UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1195

Washington, D. C. ▼ March, 1924

STERILITIES OF WILD AND CULTIVATED POTATOES WITH REFERENCE TO BREEDING FROM SEED.

By A. B. Stout, *Director of Laboratories, New York Botanical Garden, and* C. F. Clark, *Horticulturist, Office of Horticultural Investigations, Bureau of Plant Industry.*

has frederick 18

CONTENTS.

INTRODUCTION.

The importance of the reproduction of the potato from seed balls is shown by the fact that nearly all of the most valuable varieties now in cultivation have been thus obtained. A few, however, are claimed to have originated as bud sports, but these have played a relatively unimportant part in potato production. Through seed propagation there have been developed numerous varieties, differing in habit of growth, in time of maturity, in size, shape, and quality of tubers, and in adaptability to conditions in different localities. While there is still chance for further improvement regarding these characteristics, the most immediate demand for seed reproduction is in the need for varieties resistant to disease. The rapid spread of diseases of the potato during recent years, particularly the extremely infectious diseases of the mosaic and leaf-roll types that are transmitted by aphids, makes breeding for resistance to disease highly desirable, if not necessary.

The greatest difficulty encountered in the breeding of the potato from seed is the marked sterility or lack of fruitfulness very generally present. This has been experienced by all who have sought to breed this plant. Many observations have been made with reference to the various aspects of fruitlessness, and numerous views have been expressed regarding the causes and conditions involved. No clear outline of this situation with reference to the distinctions between the several types of sterility now known to be present in other

plants, however, has been drawn, and no adequate survey of the varieties by studies of the viability of their pollen has been made. It is this which the writers of this bulletin have attempted. The large number of varieties and seedlings grown at Presque Isle., Me., on the experimental plats of the Bureau of Plant Industry, located on the Aroostook Farm of the Maine Agricultural Experiment Station, afforded an abundance of material for the study. For three years (1920, 1921, and 1922) several varieties, a few unnamed stocks of seedling origin, and many seedlings directly from seed were grown at the New York Botanical Garden for comparison of their flowering and fruiting habits under different conditions. As a basis for determining the ability of varieties to produce fruit the records of the controlled pollinations made in the Bureau of Plant Industry during the period from 1914 to 1922, inclusive, have been utilized. (See Table 1.)

It is to be noted that any type of sterility or combination of several types which happens to be characteristic of an individual plant grown from seed is continued in the asexual progeny of that plant, except for possible changes in bud variations. Thus, in a clon such as the Irish Cobbler variety of potato all the plants are branches of one original seedling. If this plant was a sex intergrade with a femaleness well developed and with a low grade of maleness, the particular degrees to which maleness and femaleness were relatively developed, either uniformly or in cyclic changes for the plant, are maintained in fields of the variety grown years after. The same will be true in respect to other types of sterility which may be present, except perhaps sterilities due to the invasion of specific organisms or that may accompany the various infectious diseases.

GENERAL SURVEY OF THE TYPES OF STERILITY IN THE POTATO.

STERILITY DUE TO NONFLOWERING.

The nonblooming habit is more or less strongly developed in the cultivated varieties of the potato and is a most decided restriction to fruit and seed production. Some varieties have even been considered completely nonblooming, at least in some localities.

In an excellent account of the nonblooming habit in the potato, East (*4*)[1] concludes that "all varieties do bloom under conditions of environment to which they are adapted." He points out that there are numerous gradations between the nonblooming condition and the condition of profuse blooming, such as abscission of all buds before the flowers open, the opening of a few flowers which immediately fall, and the persistence of flowers for several days. In the first two conditions named, flowers can not function as females in seed production, and the production of viable pollen in such flowers is scarcely to be expected.

Variations in blooming for a single variety, both in different localities in the same season and in the same locality in different seasons, are noted everywhere that potatoes are grown. Of 30 standard varieties grown at the New York Botanical Garden in 1920 and 1921 none produced flowers that opened. The same varieties bloomed in profusion at Presque Isle, Me., in the experimental plats of the Bureau of Plant Industry. At both places good crops of tubers were obtained.

---

[1] Serial numbers (italic) in parentheses refer to "Literature cited," at the end of this bulletin.

In the following year (1922) a comparison test for blooming was made as follows: Of 13 commercial varieties and of 2 promising seedling strains, 15 tubers each were selected from stock grown at Presque Isle. Each tuber was cut lengthwise in halves, which were numbered in duplicate and in series. One set was planted at Presque Isle and the other at the New York Botanical Garden. The Clio and McIntyre varieties bloomed well at the botanical garden, but more abundantly at Presque Isle; Keeper, Switez, and Seedling 24642 produced few flowers at the botanical garden, but bloomed abundantly at Presque Isle; Australian Blue, Early Ohio, Early Rose, Evergreen, Green Mountain, Hamakua, Irish Cobbler, Rural New Yorker, Triumph, and Seedling 40568 bloomed abundantly at Presque Isle, but not a flower opened at New York. In most cases the nonblooming plants produced flower buds, and in some cases these developed to the degree of showing the color of the corolla, but abscission occurred before the corollas expanded.

The different results obtained from the plants grown from the two halves of tubers illustrate well the influence of environmental conditions on the blooming of any single variety. The different results obtained for different varieties grown in 1922 under the same conditions at the New York Botanical Garden also illustrate clearly the varietal differences in response to the same conditions in a single locality.

That varieties of the potato may thrive and yield good crops of tubers under conditions that do not admit of flower production is in harmony with the well-known fact that species of plants may thrive beyond their range of natural blooming. It has long been recognized that the formation of reproductive organs in all sorts of plants is greatly influenced and often even determined by external and environmental influences such as light, temperature, and the kind and quantity of food. By controlling such conditions experimentally (see especially Klebs, *10, 11, 12, 13*) many plants may be thrown into a relatively permanent vegetative condition. The influence of light and length of day on the blooming of plants has recently been emphasized by Garner and Allard (*5*). That such conditions may also exist in nature for certain zones in the distribution of plants has recently been shown by Setchell (*20, 21*).

In widely extending the cultivation of the potato, the plant is now often grown under environmental conditions that do not admit of flower formation. The fruitlessness involved in the nonflowering habit and the abscission of flowers is to be regarded as a direct influence of environment. It is an acquired or enforced sterility. Whether the flowers when produced will be of one grade of intersex or another, or whether there will be physiological incompatibilities of one degree or another, or whether there may still be some other type of sterility is quite another question.

In general, the potato is to be recognized as a cool-season crop. Nearly if not all varieties bloom in profuseness in the region about Presque Isle, Me., where the summers are cool and the growing season is only about 100 days. But even here variations from season to season are in evidence. In such sections breeding from seed may well be undertaken. Farther south local conditions may in some sections favor blooming, or planting at a particular time may bring crops into development at a season which favors formation of flowers,

quite as Newman and Leonian (*17*) have determined for certain sections of South Carolina. Breeding the potato can scarcely be undertaken at the New York Botanical Garden with any hope of continued yearly success, and this is the situation in many other sections. The first condition necessary for the successful breeding of the potato is that of certain and profuse blooming, and it is useless to undertake breeding unless the environmental conditions strongly favor the development of flowers.

STERILITY FROM ONE-SIDED IMPOTENCE, OR INTERSEXUALISM.

When flowers are produced by a variety of the potato, the condition of the sex organs as to morphological perfection and potency is a very important factor in seed production. Two types of sterility are especially concerned with the lack of potency: (1) The sterility of hybridity which typically affects both male and female organs alike and (2) the condition of intersexes which tends to give a one-sided sterility or abortion. In intersexes, especially from the standpoint of breeding, it is desirable to determine whether a plant or a clonal variety is able to function as a hermaphrodite, as a female, as a male, or perhaps as neither.

A study of maleness and of the grades of pollen sterility present in a variety may be made by an examination of the stamens as to the size of the pollen chambers and their dehiscence, of the pollen as to its appearance and its viability in proper tests for germination, and of the ability of the pollen to function in fertilization when used to pollinate varieties known to be highly capable of producing fruit.

The best experimental evidence regarding the potency of pistils, or the femaleness of a plant, is obtained by testing for fruit production by proper pollination with pollen known to be highly functional. Such tests, subject to experimental error, are adequate provided there are no marked variations in the potency of the pollen and that other types of sterility, particularly physiological incompatibilities, are not involved.

METHODS OF STUDY.

In making a special study of the anthers of varieties of the potato grown at Presque Isle, mature anthers ready to dehisce were fixed in Flemming's fixing solution, properly embedded in paraffin, sectioned by microtome, and stained with iron haematoxylin. The sections revealed the size and shape of the pollen chambers and the relative quantity of pollen, with some indication regarding the extent of abortion of grains (Pl. I, figs. 1–6).

For more direct and exact studies the pollen of fully dehiscing anthers may be placed in water. Examination with a microscope shows that some grains swell and become plump and that others remain shriveled and are obviously empty. This test was employed by Salaman (*18*) and by Salaman and Lesley (*19*) in judging pollen sterility and fertility.

The judgment of the condition of pollen in the studies here reported was based on microscopical examination of pollen from healthy plants and pollen tubes after the grains had been on an agar-sugar culture medium placed in a moist chamber for a period of 18 to 24 hours. If there was any question regarding the condition of the pollen or the germination the acetocarmine stain was added. This stain shows

that often many of the grains which swell and become plump may contain very little granular material. These tests alone show that the relative number of pollen grains aborted is high for many varieties and that for others the pollen is evidently unable to function at all. The method of culture utilized gave excellent germination, affording a reliable test for the relative viability of pollen.

Extensive tests were made to determine the most favorable medium for testing the viability of pollen. Parallel series of cultures were made with the following media: (*a*) Cane sugar in percentages of 5, 7½, 10, 12½, 15, 17½, 20, 22½, 25, 27½, and 30 in both tap and distilled water; (*b*) dextrin in the same percentages; (*c*) the addition of 1 per cent agar to both *a* and *b*; (*d*) the addition to *a*, *b*, and *c* of the extract of pistils made by grinding 10 pistils in 1 cubic centimeter of water and filtering. In 1921 duplicate series involving a total of several thousand tests were made for all these media, using pollen of varieties and species which had previously given the best results.

No germination was obtained with the use of any liquid medium. The 7 per cent sugar solution reported by East (*4*) as giving germination was also used in every set of tests made in 1921 for 45 varieties. The good pollen grains would swell to rotundity and small protrusions appear at the various pores quite as shown by East (*4*), but in this, as in all other liquid media, no real germination was observed. Excellent germination was obtained, however, with 1 gram agar and 15 grams cane sugar in 100 cubic centimeters of distilled water. Occasionally 10, 12½, 17½, and 20 per cent sugar with 1 per cent agar gave nearly as good germination. The sugar-agar media were made up in bulk, run into test tubes, and sterilized. A fresh tube of each grade was used each day. About one-fifth of a cubic centimeter of a warmed and liquefied medium was placed on a glass slide so that it spread out into a flat-topped circular drop about 1½ centimeters in diameter and solidified. Pollen from dehiscing anthers was sprinkled on the surface and the slide placed in a moist chamber at room temperatures. During the season of 1922 the tests were made with the 10+1, 15+1, and 20+1 sugar-agar media, and the moist chambers were kept overnight in a constant-temperature chamber set at a minimum of 20° C. Final judgment of germination was made after 24 hours.

Plates II to VI, inclusive, are photomicrographs of cultures on 1 per cent agar+15 per cent sugar kept in a moist chamber 24 hours and then stained with acetocarmine. The imperfect grains, containing little or no granular material, did not take the stain.

ANTHERS AND POLLEN OF SUPPOSEDLY WILD SPECIES.

Solanum chacoense.—The anthers of *S. chacoense* are plump, with well-rounded and proportionately large pollen chambers (Pl. I, fig. 1). At least 99 per cent of the pollen from plants which flowered during the period of the studies was plump and filled with granular material. On 25 per cent sugar and 1 per cent agar only short pollen tubes formed from about 5 per cent of the pollen; on 20 + 1 medium about 10 per cent of the grains germinated; on the 15 + 1 medium more than 90 per cent of the pollen grains germinated, the length of many tubes being 800 μ while some were 1,050 μ in length; on 10 + 1 medium about 20 per cent of the pollen germinated; on 7½ + 1

medium very few grains germinated. This species gave the most vigorous and highest percentage of germination seen in any of the tests (Pl. II, fig. 1).

Solanum fendleri.—The anthers of *S. fendleri* possess large pollen chambers (Pl. I, fig. 2), with an abundance of pollen. Examination and tests for germination were made of pollen of 32 different plants. There was a rather wide variation in the size of the pollen grains that were plump, and there were always some grains shriveled and empty. There was always good germination, however, with many tubes as long as 800 μ (Pl. II, fig. 2).

Solanum jamesii.—The pollen chambers in the anthers of *S. jamesii* are rather narrow (Pl. I, fig. 3), in comparison to those of *S. chacoense.* The anthers dehisce fully and shed an abundance of pollen. Examinations and tests for germination were made of the pollen of 21 plants. Two of these plants produced only a few plump grains, none of which germinated; for the others, the quantity of aborted pollen ranged from one-tenth to two-thirds of all grains, but the germination was excellent with tubes as much as 600 μ in length. There was more pollen sterility in this species than in the two previously noted (Pl. III, fig. 1).

Solanum maglia.—The anthers of all plants of *S. maglia* grown at Presque Isle in 1922 were well matured, dehiscence was excellent, and pollen was abundant. Only five plants bloomed during the period of the study of pollen, and at least 90 per cent of the grains of these were empty and shriveled (Pl. III, fig. 2). In numerous tests for germination involving many thousands of grains only a few short pollen tubes were observed. The plants of this species which were studied appeared to be almost, if not completely, pollen sterile.

ANTHERS AND POLLEN OF CULTIVATED VARIETIES.

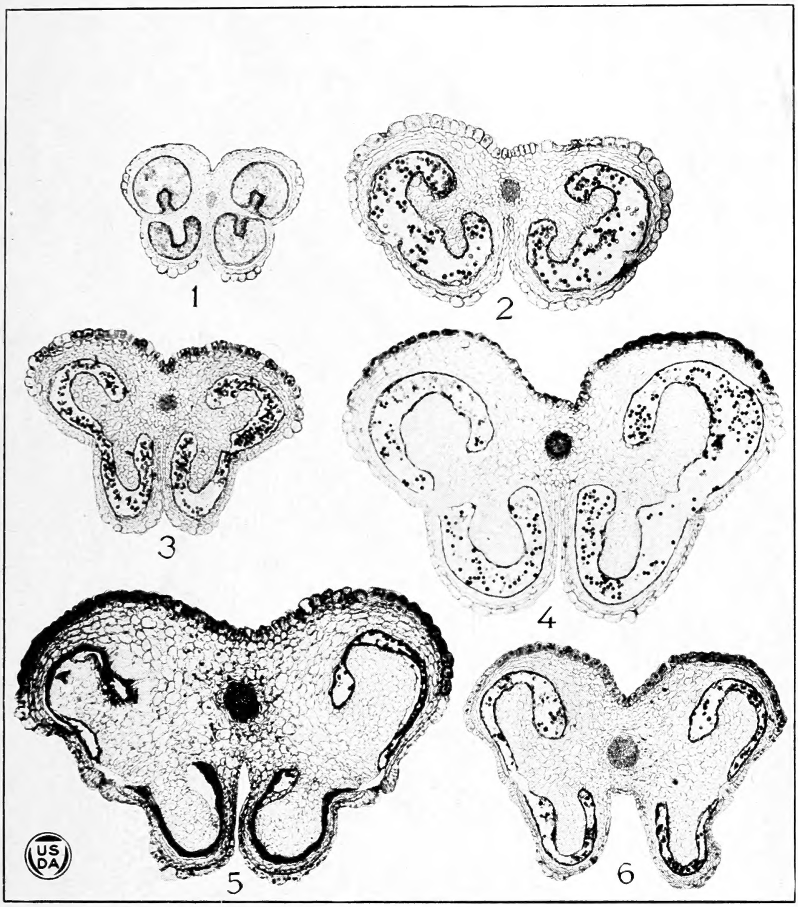
Special study was made of the anthers and pollen of healthy plants of 132 named varieties, chiefly commercial, from different parts of the world and of 78 seedlings, all grown at Presque Isle. Noticeable differences were found in the relative lengths of pistils and stamens, in the size, color, plumpness, and dehiscence of stamens, and in the quantity of pollen and its viability. In decided cases of abortion and impotence of stamens the anthers are green or pale green throughout at the time of full maturity, with no dehiscence and little or no sporogenous tissue.

On the basis of the condition of the anthers, the quantity of pollen shed, the relative number of grains possessing granular contents, and the extent and vigor of germination of pollen, the cultivated varieties may be grouped into four classes, as follows:

Class 1.—Anthers well developed, richly orange colored; dehiscence very regular and complete; pollen abundant with at least 30 per cent becoming plump and containing granular material; germination good with pollen tubes on culture media often 500 μ in length but seldom more than 15 to 20 per cent of all grains germinating.

The McCormick and Busola may be considered in detail as two of the varieties with the best development of anthers and pollen. The anthers are large and well developed, the pollen chambers are ample (Pl. I, fig. 4), and dehiscence is excellent. Pollen is abundantly shed, and about half of all pollen grains contain granular material and become plump on the media used in testing germination. On the 15 per cent sugar plus 1 per cent agar medium, which gave the best germination, there was germination of 5 to 10 per cent of all grains, with tubes often 500 μ in length. About half of the pollen is shriveled and empty and does not fill out plumply when placed on the

6a



CROSS SECTIONS OF POTATO ANTHERS.

FIG. 1.—Solanum chacoense. × 36. FIG. 2.—Solanum fendleri. × 49. FIG. 3.—Solanum jamesii. × 36. FIG. 4.—McCormick. × 36. FIG. 5.—Australian Blue. × 49. FIG. 6.—Green Mountain. × 36.

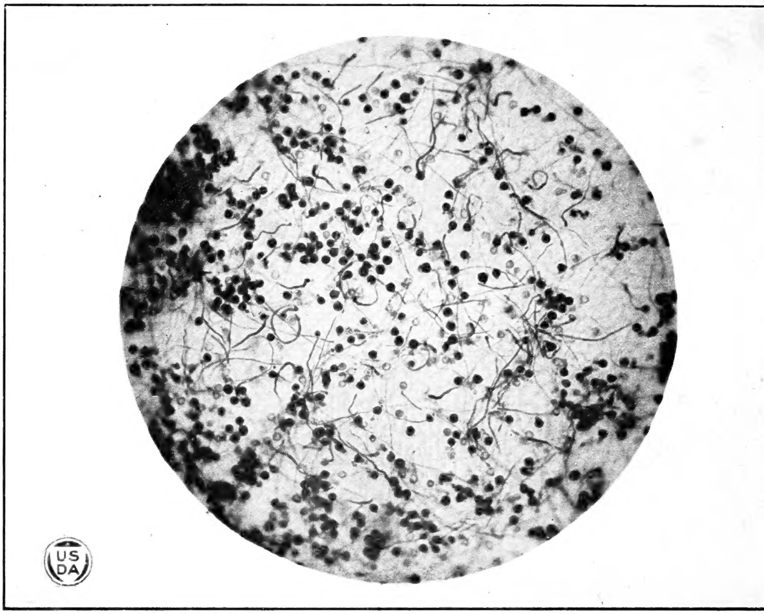


FIG. 1.—POLLEN OF SOLANUM CHACOENSE. ×50.

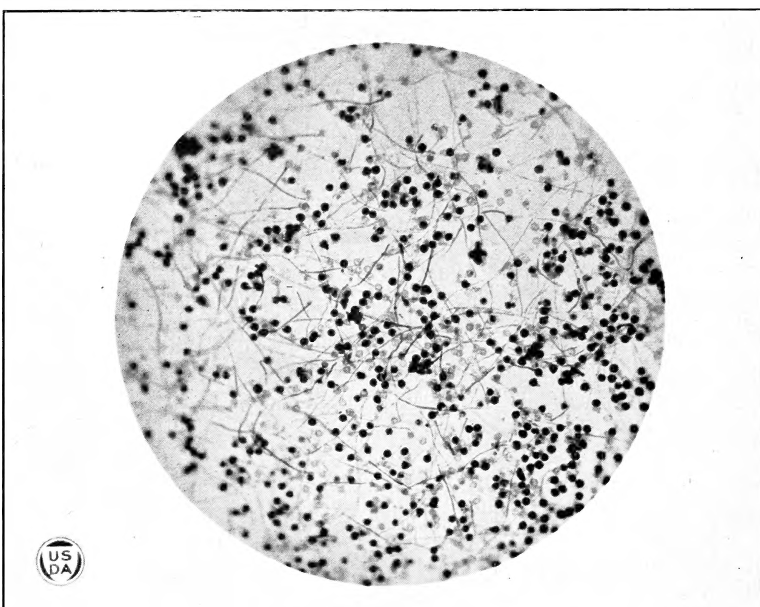


FIG. 2.—POLLEN OF SOLANUM FENDLERI. ×50.

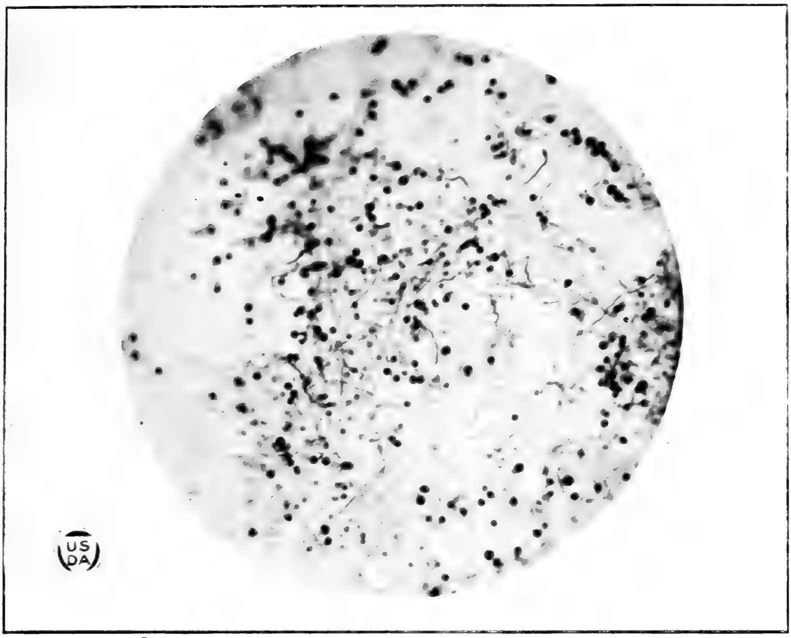


FIG. 1.—POLLEN OF SOLANUM JAMESII. ×50.

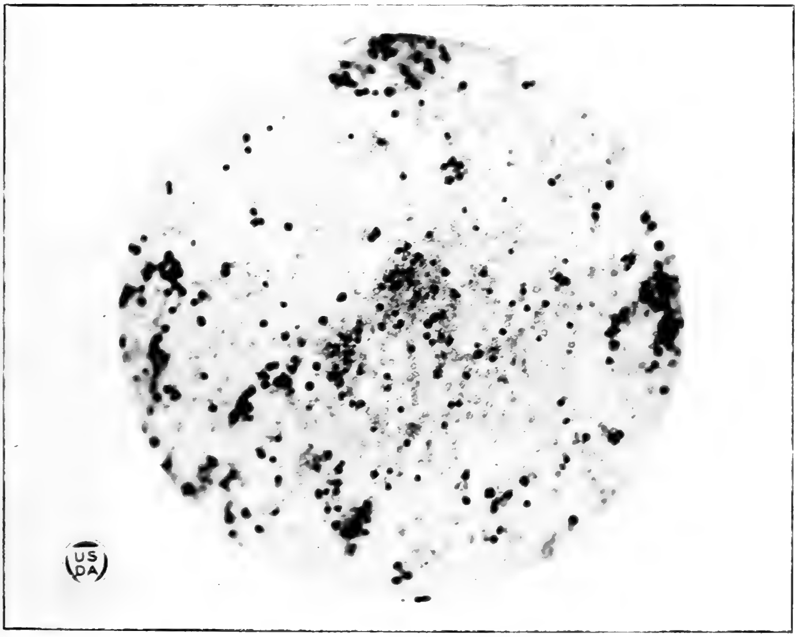


FIG. 2.—POLLEN OF SOLANUM MAGLIA. ×50.

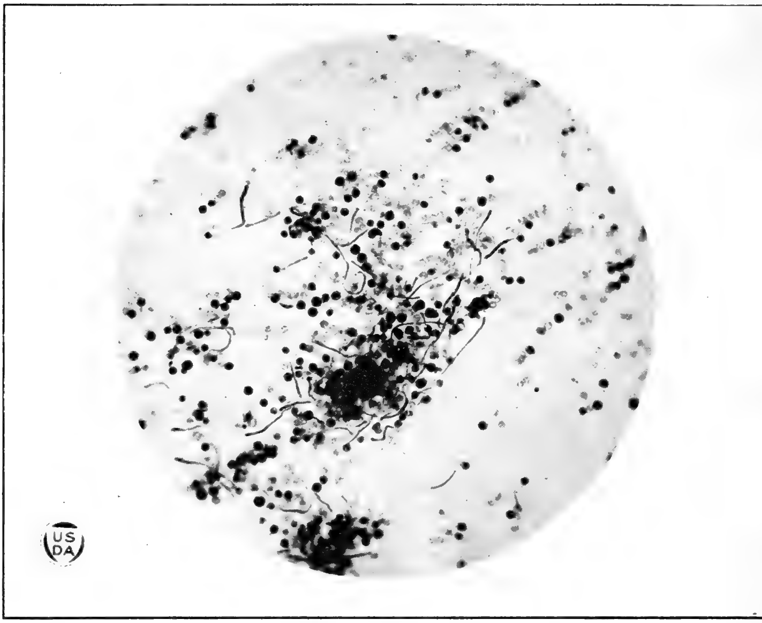


FIG. 1.—POLLEN OF MCCORMICK. ×50.

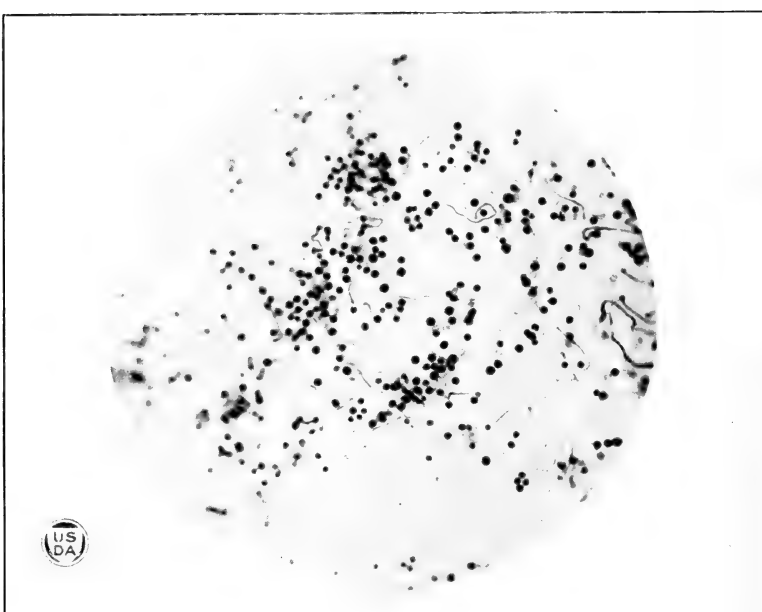


FIG. 2.—POLLEN OF BUSOLA. ×50.

FIG. 1.—POLLEN OF GREEN MOUNTAIN. ×50.

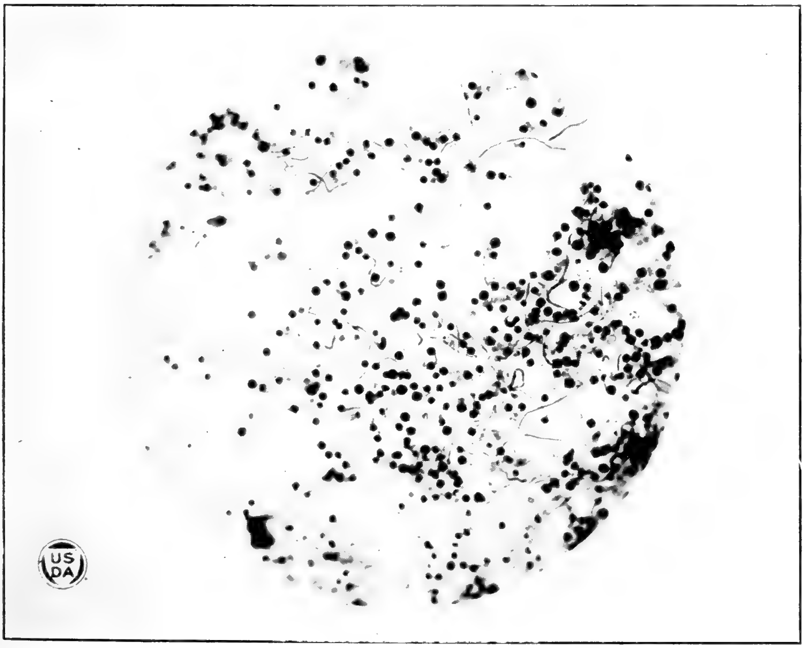


FIG. 2.—POLLEN OF SEEDLING 39477. ×50.

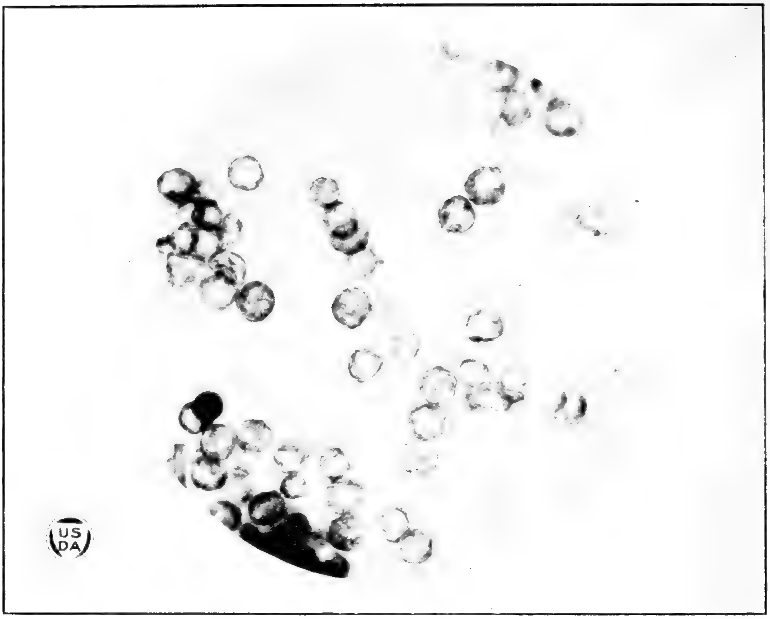


FIG. 1.—POLLEN OF IRISH COBBLER. ×220.

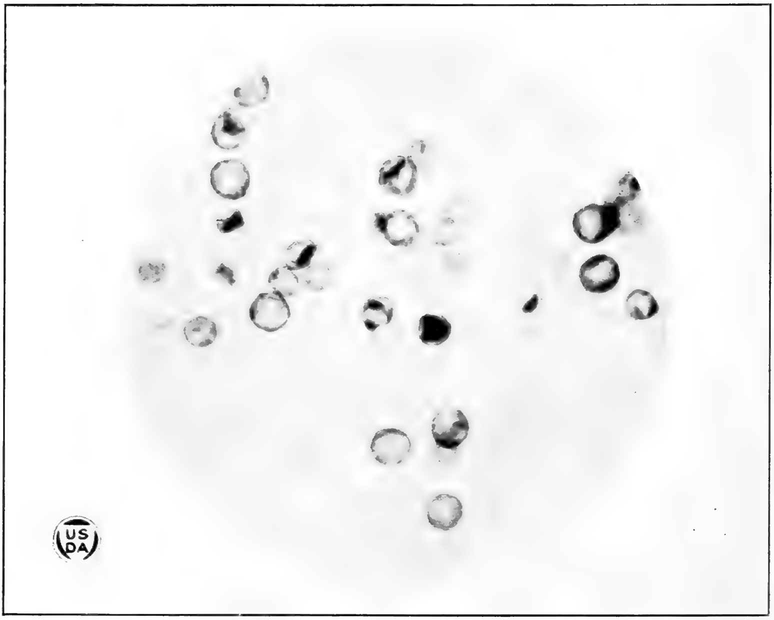


FIG. 2.—POLLEN OF TRIUMPH. ×220.

media (Pl. IV, figs. 1 and 2). Thus, in the best pollen bearers of the cultivated varieties there is much impotence of pollen, and the relative number of grains that germinate is low. Varieties with such pollen, however, have a record of being able to function best as pollen parents.

Class 2.—In general appearance and dehiscence anthers of class 2 are like those in class 1; the percentage of plump pollen is low (5 per cent to less than 30 per cent), with only a few of these grains germinating. Usually the tubes are of feeble growth, but for some varieties listed here tubes 250 μ long were observed for a very few grains.

Green Mountain is fairly typical of this class. The pollen chamber is less spacious than in McCormick (Pl. I, fig. 6). From the examinations of 30 mounts of pollen, mostly on 15 + 1 media it appeared that from 5 to 10 per cent of all grains have granular contents but that less than 1 per cent of all pollen could germinate, and the tubes for all these were short (Pl. V, fig. 1). In some cultures of pollen of the Green Mountain no germination was seen.

The record for crosses with pollen of this class quite uniformly shows poor results. Green Mountain selfed on 115 flowers gave only 2 seed balls; on 51 varieties and seedlings its pollen failed in 44 combinations, and of the 806 flowers involved only 57 set fruit. Yet pollen of Green Mountain on McCormick in one set of crosses gave 27 fruits for 44 flowers pollinated, an individual record that is exceedingly high for pollen of any plant in this class.

Class 3.—Anthers usually well developed, occasionally remaining somewhat greenish at apex; dehiscence of nearly all stamens good, but in some varieties poor for some stamens; pollen usually scant, but sometimes fairly abundant; percentage of plump grains low (usually less than 10 per cent and often less than 1 per cent), rarely giving germination, and failing in numerous crosses on varieties known to set fruit readily when viable pollen is used.

As a class, the plants here listed have poorer pollen than those of class 2. Possibly the making of a large number of germination tests would show some germination of pollen for plants here listed in class 3. The Australian Blue variety is in this class. The anthers are large and well developed and dehisce fully, but the pollen chambers are narrow (Pl. I, fig. 5), pollen is scant, and there is seldom a plump grain. The shriveled pollen is aggregated in irregular and rather compact masses, as shown in the illustration. The empty and in some cases shrunken pollen grains of the Irish Cobbler and Triumph, which also belong in this class, are shown in Plate VI, Figures 1 and 2, respectively.

The records of crosses made by the Bureau of Plant Industry show that only a few of the varieties of this class have been used as pollen parents in crosses with varieties known to be good seed parents. Irish Cobbler pollen occasionally showed a very few pollen tubes in the germination tests, but the use of pollen of this variety in crosses on 12 varieties with a total of 156 flowers failed in every case. Early Rose pollen failed completely on 8 varieties involving 83 flowers. Such failures are to be expected from the appearance of pollen of these varieties and its lack of germination on media.

Class 4.—Anthers mostly greenish; dehiscence irregular, with some or even all anthers failing to open; pollen very scant, with scarcely a plump grain, or pollen grains lacking. No germination.

In Rose No. 4, which belongs in this class, the anthers are greenish yellow; the dehiscence is irregular, with some anthers failing to open; the pollen is scant, with very rarely a plump grain. The Russet Burbank variety has some orange-colored anthers, but many are greenish, tapering at apex, indehiscent, and no good pollen was observed. Berrick and Sensation illustrate well the condition in which anthers are decidedly undersized, greenish, and almost, if not completely, indehiscent. It is obvious that varieties belonging in this class can rarely ever function as pollen parents.

These observations and the tests for germination give results that fully support the very general view that pollen sterility is a condition which accounts for much of the failure of fruit production in potatoes. In the cultivated varieties and also in certain wild species there is a very general impotence of pollen.

The varieties grouped in class 1 are the only ones of those studied which can with reason be expected to function at all well as male parents, and even in the best of these a large percentage of the pollen is impotent. Possibly a few of the plants in class 2 can function occasionally as pollen parents, and if pollen germinates more readily on pistils than on artificial media perhaps varieties in class 3 may sometimes function as pollen parents under specially favorable conditions.

THE ABILITY OF CULTIVATED VARIETIES TO PRODUCE SEED.

The innate ability of varieties to produce seed can be judged best when the pollinations involve pollen that is most highly potent and viable and are made when flowers open in abundance. Results from proper pollinations with pollen varieties placed in class 1, especially of McCormick, Keeper, Busola, Clio, McIntyre, and Seedling 24642, are much more reliable than when pollen of varieties in class 2 are used, and from the results of such crosses the following classes may be made with reference only to ability to produce fruit:

Class A.—Varieties highly productive of seed balls when pollen of varieties in class 1 is used.
Class B.—Feeble production of seed balls to the viable pollen of varieties in class 1.
Class C.—No production of seed balls with seed to any pollination.
Class D.—A fourth grouping, designated as class D, may be made on the basis of the tendency to produce parthenocarpic and seedless fruits evidently without fertilization.

A survey of the results of pollinations reported by Stuart (*24*) and those here recorded in Table 1 shows that when blooming well, many varieties readily produce seed balls provided pollen known to be viable is used.

TABLE 1.—*Potato crosses grouped according to pollen parent recorded by the United States Department of Agriculture during the 9-year period from 1914 to 1922, inclusive.*

[The crosses recorded for the years 1914 to 1918, inclusive, were made by William Stuart, P. M. Lombard, and others.]

Date of crossing.	Parents.	Classes involved in cross.	Number of— Flowers crossed.	Number of— Seed balls produced.	Percentage of success.
May 26, 1921	Burbank × American Giant	—×3	41	0	0
Aug. 11, 1915	White McCormick × American Wonder	A×—	16	0	0
Aug. 7, 1914	Burbank × Beauty of Hebron	—×3	1	0	0
Aug. 8, 1914	Green Mountain × Beauty of Hebron	A×3	18	0	0
	Total and average		19	0	0
Aug. 10, 1914	British Queen × Bohun	B×1	16	0	0
Aug. 8, 1914	Rust Proof × Bohun	—×1	14	0	0
Do.	State of Maine × Bohun	—×1	5	0	0
	Total and average		35	0	0
Aug. 7, 1914	Acme × Busola	A×1	2	1	50.00
Do.	Beauty of Hebron × Busola	A×1	9	7	77.78
Aug. 10, 1914	British Queen × Busola	B×1	12	0	0
Aug. 13, 1915	Cacha Negra (S. A. No. 7) × Busola	A×1	39	17	43.59
Aug. 10, 1914	Carman No. 3 × Busola	A×1	17	8	47.06
Aug. 8, 1914	Charles Downing × Busola	B×1	6	0	0
Aug. 7, 1914	Country Gentleman × Busola	A×1	8	5	62.50
Do.	Early Michigan × Busola	A×1	8	7	87.50
Do.	Early Rose × Busola	A×1	10	6	60.00
July 28, 1916	....do	A×1	9	8	88.89
Aug. 7, 1914	Early Thoroughbred × Busola	—×1	4	0	0
Aug. 8, 1914	Farmer × Busola	—×1	15	2	13.33
Aug. 7, 1914	Flourball × Busola	A×1	6	3	50.00
Do.	Garnet Chili × Busola	A×1	16	6	37.50
July 28, 1916	.....do	A×1	8	4	50.00
Aug. 8, 1914	Gold Coin × Busola	A×1	5	1	20.00
Do.	Green Mountain × Busola	A×1	2	0	0
Aug. 9, 1915	.....do	A×1	40	17	42.50
July 27, 1916	.....do	A×1	68	20	29.41
Aug. 7, 1914	Irish Cobbler×Busola	A×1	17	10	58.82
Aug. 15, 1915	.....do	A×1	296	119	40.20
July 29, 1916	.....do	A×1	128	82	64.06
Aug. 8, 1914	Late Blightless×Busola	A×1	17	7	41.18
Aug. 10, 1914	Late Vicktor×Busola	A×1	6	5	83.33
Aug. 10, 1915	Manila×Busola	A×1	48	31	64.58

TABLE 1.—*Potato crosses grouped according to pollen parent recorded by the United States Department of Agriculture during the 9-year period from 1914 to 1922, inclusive*—Continued.

Date of crossing.	Parents.	Classes involved in cross.	Number of— Flowers crossed.	Number of— Seed balls produced.	Percentage of success.
Aug. 10, 1914	McCormick×Busola	A×1	9	3	33.33
July 28, 1916	....do	A×1	80	59	73.75
Aug. 7, 1914	New Scotch Rose×Busola	A×1	14	7	50.00
Aug. 10, 1914	Non Blight×Busola	A×1	11	8	72.73
Aug. 10, 1915	.....do	A×1	27	19	70.37
Aug. 8, 1914	Norcross×Busola	A×1	10	4	40.00
Aug. 10, 1915	President Roosevelt×Busola	A×1	78	16	20.51
Aug. 10, 1914	Prosperity×Busola	A×1	15	10	66.67
Aug. 8, 1914	Radium×Busola	—×1	23	0	0
Aug. 10, 1914	Rural New Yorker×Busola	A×1	9	6	66.67
Aug. 3, 1915	.....do	A×1	40	29	72.50
Aug. 8, 1914	Rust Proof×Busola	—×1	11	1	9.09
Aug. 13, 1915	Seedling 18714×Busola	A×1	83	51	61.45
Aug. 7, 1914	Seneca Beauty×Busola	A×1	19	5	26.32
Aug. 10, 1914	Sir Walter Raleigh×Busola	A×1	10	8	80.00
Aug. 13, 1915	Solanum sp. (S. A. No. 6)×Busola	—×1	65	3	4.62
Aug. 8, 1914	State of Maine×Busola	—×1	4	0	0
Aug. 7, 1914	Vigorosa×Busola	A×1	7	6	85.71
Aug. 11, 1915	White McCormick×Busola	A×1	5	2	40.00
July 28, 1916	Yellow-fleshed variety×Busola	A×1	7	7	100
	Total and average		1,323	610	46.11
Aug. 10, 1915	Bull Moose×Cacha Negra (S. A. No. 7)	—×1	28	2	7.14
Aug. 16, 1915	Busola×Cacha Negra (S. A. No. 7)	A×1	31	12	38.71
Aug. 10, 1915	Dibble's Russet×Cacha Negra (S. A. No. 7)	A×1	19	9	47.37
Do	Green Mountain×Cacha Negra (S. A. No. 7)	A×1	48	9	18.75
Do	Manila×Cacha Negra (S. A. No. 7)	A×1	25	13	52.00
Aug. 13, 1915	Norcross×Cacha Negra (S. A. No. 7)	A×1	49	23	46.94
	Total and average		200	68	34.00
Aug. 7, 1914	Beauty of Hebron×Cedon	A×3	11	0	0
Aug. 8, 1914	Gold Coin×Cedon	A×3	9	0	0
Aug. 10, 1915	Green Mountain×Cedon	A×3	29	0	0
Aug. 7, 1914	Irish Cobbler×Cedon	A×3	8	0	0
Aug. 8, 1914	McKinley×Cedon	—×3	3	0	0
Aug. 7, 1914	New Scotch Rose×Cedon	A×3	6	0	0
Do	White Elephant×Cedon	A×3	4	0	0
	Total and average		70	0	0
July 16, 1921	American Giant×Clio	A×1	15	0	0
July 30, 1921	.....do	A×1	4	0	0
Aug. 2, 1921	.....do	A×1	4	0	0
July 23, 1919	Commandant×Clio	—×1	53	0	0
July 22, 1920	Cummings' Pride×Clio	B×1	17	0	0
Aug. 5, 1917	Doma (S. A. No. 18)×Clio	—×1	2	0	0
July 18, 1919	Seedling 11844×Clio	A×1	6	0	0
July 20, 1920	.....do	A×1	5	0	0
July 22, 1920	.....do	A×1	22	5	22.73
July 21, 1921	.....do	A×1	6	0	0
July 25, 1921	.....do	A×1	5	0	0
Do	Seedling 37662×Clio	A×1	13	3	23.08
July 18, 1919	Seedling 38774×Clio	A×1	13	2	15.38
Aug. 5, 1917	Solanum sp. (S. A. No. 37)×Clio	—×1	3	0	0
Do	Solanum sp. (S. A. No. 92)×Clio	—×1	2	0	0
Aug. 6, 1917	Solanum sp. (S. A. No. 148)×Clio	—×1	6	0	0
	Total and average		176	10	5.68
July 31, 1919	Clio×Commandant	A×—	49	1	2.04
Aug. 6, 1917	Congo×Commandant		5	0	0
Do	Green Mountain×Commandant	A×—	8	0	0
Aug. 5, 1917	Morada (S. A. No. 84)×Commandant		4	0	0
July 17, 1919	Seedling 38774×Commandant	A×—	5	0	0
Aug. 5, 1917	Solanum sp. (S. A. No. 37)×Commandant		2	0	0
Aug. 6, 1917	Solanum sp. (S. A. No. 148)×Commandant		1	0	0
Do	Solanum sp. (S. A. No. 152)×Commandant		4	0	0
	Total and average		78	1	1.28

TABLE 1.—*Potato crosses grouped according to pollen parent recorded by the United States Department of Agriculture during the 9-year period from 1914 to 1922, inclusive*—Continued.

Date of crossing.	Parents.	Classes involved in cross.	Number of— Flowers crossed.	Number of— Seed balls produced.	Percentage of success.
Aug. 7, 1914	Early Petoskey×Early Eureka	—×4	7	0	0
Do	Early Standard (Dreer's)×Early Eureka	—×4	13	0	0
Do	Early Vicktor×Early Eureka	—×4	14	0	0
Do	Flourball×Early Eureka	A×4	3	0	0
Do	Irish Cobbler×Early Eureka	A×4	4	0	0
July 30, 1915	Pearl×Early Eureka	—×4	3	0	0
Do	White Triumph×Early Eureka	—×4	18	0	0
	Total and average		62	0	0
Aug. 7, 1914	Early Albino×Early Petoskey	—×3	7	0	0
Do	Early Michigan×Early Petoskey	A×3	7	0	0
Do	Early Petoskey×Early Petoskey	—×3	3	0	0
Do	Early Rose×Early Petoskey	A×3	4	0	0
Do	Early Standard (Dreer's)×Early Petoskey	—×3	6	0	0
Do	Early Thoroughbred×Early Petoskey	—×3	4	0	0
Do	Early Vicktor×Early Petoskey	—×3	5	0	0
Do	Flourball×Early Petoskey	A×3	10	0	0
Do	Irish Cobbler×Early Petoskey	A×3	5	0	0
July 22, 1916	Triumph×Early Petoskey	B×3	7	0	0
	Total and average		58	0	0
Aug. 7, 1914	Acme×Early Rose	—×3	5	0	0
Do	Early Eureka×Early Rose	—×3	20	0	0
Do	Early Petoskey×Early Rose	—×3	2	0	0
Do	Early Rose×Early Rose	A×3	7	0	0
Do	Early Standard (Dreer's)×Early Rose	—×3	5	0	0
July 28, 1916	Garnet Chili×Early Rose	A×3	37	0	0
Aug. 6, 1917	Manani (S. A. No. 191)×Early Rose	—×3	4	0	0
Do	Solanum sp. (S. A. No. 128)×Early Rose	—×3	3	0	0
	Total and average		83	0	0
Aug. 7, 1914	Early Standard (Dreer's)×Early Standard (Dreer's)		4	0	0
Do	Early Vicktor × Early Standard (Dreer's)		4	0	0
July 22, 1916	Truimph×Early Standard (Dreer's)	B×—	21	0	0
	Total and average		29	0	0
Aug. 7, 1914	Early Michigan×Early White Albino	A×—	4	0	0
July 28, 1916	McCormick×Early White Albino	A×—	64	48	75.00
Do	Round Pinkeye×Early White Albino		28	0	0
	Total and average		96	48	50.00
Aug. 10, 1914	British Queen × Farys	B×—	10	0	0
Do	Non Blight×Farys	A×—	8	6	75.00
Do	Prosperity×Farys	A×—	8	7	87.50
Do	Sir Walter Raleigh×Farys	A×—	9	8	88.89
	Total and average		35	21	60.00
July 30, 1915	White Truimph×Flourball (Johnson's)		17	0	0
July 28, 1916	Early Rose×Garnet Chili	A×2	30	0	0
Do	Perfect Peachblow×Garnet Chili	—×2	25	0	0
	Total and average		55	0	0
July 27, 1916	Green Mountain×Gold Coin	A×2	61	0	0
Aug. 13, 1914	Aldona×Green Mountain	—×2	15	0	0
Aug. 7, 1914	American Wonder×Green Mountain	—×2	16	1	6.25
Do	Beauty of Hebron×Green Mountain	A×2	10	5	50.00
Aug. 13, 1914	Bohun×Green Mountain	—×2	23	0	0
Do	Busola×Green Mountain	A×2	40	0	0
Do	Cedon×Green Mountain	—×2	23	0	0
Aug. 7, 1914	Country Gentleman×Green Mountain	A×2	21	4	19.05
Aug. 3, 1914	Dibble's Russet×Green Mountain (Acc. No. 19408)	A×2	65	9	13.85
Do	Dibble's Russet×Green Mountain (Acc. No. 10789)	A×2	11	0	0
Aug. 5, 1917	Doma (S. A. No. 18)×Green Mountain	—×2	3	0	0

TABLE 1.—*Potato crosses grouped according to pollen parent recorded by the United States Department of Agriculture during the 9-year period from 1914 to 1922, inclusive*—Continued.

Date of crossing.	Parents.	Classes involved in cross.	Number of— Flowers crossed.	Number of— Seed balls produced.	Percentage of success.
Aug. 7, 1914	Early Michigan×Green Mountain	A×2	12	0	0
Do	Early Thoroughbred×Green Mountain	—×2	3	1	33.33
Aug. 13, 1914	Farys×Green Mountain	—×2	13	0	0
Aug. 5, 1917	Francesca Colorada (S. A. No. 86)×Green Mountain	A×2	8	0	0
Aug. 7, 1914	Garnet Chili×Green Mountain	A×2	15	0	0
Aug. 13, 1914	Geymin×Green Mountain	—×2	11	0	0
Do	Gracya×Green Mountain	—×2	22	0	0
July 26, 1916	Green Mountain×Green Mountain	A×2	115	2	1.74
Aug. 13, 1914	Krolewicz×Green Mountain	—×2	21	0	0
July 28, 1916	McCormick×Green Mountain	A×2	44	27	61.36
July 27, 1916	McIntyre×Green Mountain	A×2	36	0	0
Aug. 5, 1917	Morada (S. A. No. 84)×Green Mountain	—×2	1	0	0
Aug. 7, 1914	New Scotch Rose×Green Mountain	A×2	4	0	0
July 28, 1916	Perfect Peachblow×Green Mountain	—×2	9	0	0
Aug. 13, 1914	Petronius×Green Mountain	—×2	19	0	0
Aug. 5, 1917	Picun (S. A. No. 52)×Green Mountain	—×2	5	0	0
Aug. 13, 1914	Potentat×Green Mountain	—×2	37	0	0
Aug. 3, 1915	Rural New Yorker×Green Mountain	A×2	50	10	20.00
Aug. 14, 1914	Seedling 18714×Green Mountain	A×2	26	0	0
Do	Seedling 18748×Green Mountain	—×2	26	0	0
Aug. 13, 1914	Senator×Green Mountain	—×2	32	0	0
Aug. 5, 1917	Solanum sp. (S. A. No. 15)×Green Mountain	—×2	20	0	0
Do	Solanum sp. (S. A. No. 24)×Green Mountain	A×2	4	0	0
Do	Solanum sp. (S. A. No. 28)×Green Mountain	—×2	3	0	0
Do	Solanum sp. (S. A. No. 37)×Green Mountain	—×2	2	0	0
Do	Solanum sp. (S. A. No. 41a)×Green Mountain	—×2	2	0	0
Do	Solanum sp. (S. A. No. 48)×Green Mountain	—×2	4	0	0
Do	Solanum sp. (S. A. No. 69)×Green Mountain	—×2	3	0	0
Do	Solanum sp. (S. A. No. 72)×Green Mountain	—×2	3	0	0
Do	Solanum sp. (S. A. No. 92)×Green Mountain	—×2	2	0	0
Aug. 6, 1917	Solanum sp. (S. A. No. 128)×Green Mountain	—×2	4	0	0
Do	Solanum sp. (S. A. No. 148)×Green Mountain	—×2	2	0	0
Do	Solanum sp. (S. A. No. 152)×Green Mountain	—×2	6	0	0
Aug. 13, 1914	Switez×Green Mountain	A×2	32	0	0
Aug. 5, 1917	Torrenco (S. A. No. 63)×Green Mountain	—×2	1	0	0
Aug. 6, 1917	Tuquerrena Blanca (S. A. No. 182)×Green Mountain	—×2	6	0	0
July 27, 1916	Up-to-Date×Green Mountain	—×2	30	0	0
Aug. 7, 1914	Vigorosa×Green Mountain	A×2	5	0	0
Do	White Chief×Green Mountain	—×2	8	0	0
Aug. 11, 1915	White McCormick×Green Mountain	A×2	7	0	0
July 28, 1916	Yellow-fleshed variety×Green Mountain	—×2	21	0	0
Aug. 13, 1914	Zbyszek×Green Mountain	—×2	20	0	0
	Total and average		921	59	6.41
Aug. 7, 1914	Country Gentlemen×Irish Cobbler	A×3	4	0	0
Do	Early Albino×Irish Cobbler	—×3	2	0	0
Do	Early Eureka×Irish Cobbler	—×3	15	0	0
Do	Early Michigan×Irish Cobbler	A×3	14	0	0
Do	Early Petoskey×Irish Cobbler	—×3	13	0	0
Do	Early Standard (Dreer's)×Irish Cobbler	—×3	7	0	0
Do	Early Thoroughbred×Irish Cobbler	—×3	2	0	0
Do	Flourball×Irish Cobbler	A×3	5	0	0
Do	New Scotch Rose×Irish Cobbler	A×3	7	0	0
July 27, 1916	Triumph×Irish Cobbler	B×3	25	0	0
July 28, 1916	Up-to-Date×Irish Cobbler	—×3	48	0	0
July 30, 1915	White Triumph×Irish Cobbler	—×3	14	0	0
	Total and average		156	0	0
July 26, 1921	Clio×Keeper	A×1	11	5	45.45
Do	Factor×Keeper	B×1	13	0	0
	Total and average		24	5	20.83
Aug. 3, 1914	Dibble's Russet×Keystone	A×—	14	0	0
Aug. 10, 1915	Bull Moose×McCormick	—×1	29	0	0
Aug. 1, 1921	Clio×McCormick	A×1	17	0	0
Aug. 10, 1921	do	A×1	9	5	55.56
Aug. 10, 1915	Dibble's Russet×McCormick	A×1	21	5	23.81
Aug. 10, 1915	Early Rockford×McCormick	A×1	1	0	0
Aug. 9, 1915	Green Mountain×McCormick	A×1	138	1	.72

TABLE 1.—*Potato crosses grouped according to pollen parent recorded by the United States Department of Agriculture during the 9-year period from 1914 to 1922, inclusive*—Continued.

Date of crossing.	Parents.	Classes involved in cross.	Number of— Flowers crossed.	Number of— Seed balls produced.	Percentage of success.
Aug. 2, 1919	Green Mountain×McCormick	A×1	45	7	15.56
July 28, 1920	.....do	A×1	65	7	10.77
Aug. 2, 1919	Irish Cobbler×McCormick	A×1	55	30	54.55
Aug. 4, 1919	.....do	A×1	36	16	44.44
June 5, 1922	McIntyre×McCormick	A×1	9	0	0
June 7, 1922	.....do	A×1	4	0	0
June 9, 1922	.....do	A×1	1	1	100
Aug. 10, 1915	Non Blight×McCormick	A×1	22	1	4.55
June 21, 1922	Seedling 39117×McCormick	A×1	4	4	66.67
June 26, 1922	.....do	A×1	2		
Aug. 6, 1921	Seedling 41156×McCormick	A×1	9	1	11.11
Aug. 11, 1921	.....do	A×1	11	4	36.36
Aug. 19, 1921	Seedling 41361×McCormick	A×1	5	2	40.00
Aug. 1, 1921	Solanum sp. (Mexico)×McCormick	A×1	14	2	14.29
Aug. 13, 1921	Solanum tuberosum (China)×McCormick	A×1	4	4	100
	Total and average	....	501	90	17.96
July 26, 1922	Cacha Blanca (S. A. No. 8)×McIntyre	A×1	54	39	72.22
Aug. 5, 1917	Doma (S. A. No. 18)×McIntyre	—×1	4	0	0
Do	Francesca Colorada (S. A. No. 86)×McIntyre	A×1	13	6	46.15
July 28, 1916	Garnet Chili ×McIntyre	A×1	33	0	0
June 23, 1922	McCormick×McIntyre	A×1	10	3	30.00
July 7, 1922	.....do	A×1	8	2	25.00
July 13, 1922	.....do	A×1	10	10	100
July 17, 1922	.....do	A×1	6	6	100
Aug. 5, 1917	Morada (S. A. No. 84)×McIntrye	—×1	2	0	0
July 28, 1916	Perfect Peachblow×McIntyre	—×1	23	0	0
Aug. 5, 1917	Picun Negra (S. A. No. 52)×McIntyre	—×1	5	0	0
July 1, 1922	Seedling 4240×McIntyre	A×1	4	0	0
June 17, 1922	Seedling 39117×McIntyre	A×1	7	0	0
June 19, 1922	.....do	A×1	9	1	11.11
June 23, 1922	.....do	A×1	7	0	0
July 14, 1922	Seedling 39208×McIntyre	A×1	35	9	25.71
Aug. 5, 1917	Solanum sp. (S. A. No. 24)×McIntyre	A×1	3	3	100
Do	Solanum sp. (S. A. No. 28)×McIntyre	—×1	4	0	0
Do	Solanum sp. (S. A. No. 37)×McIntyre	—×1	2	0	0
Do	Solanum sp. (S. A. No. 48)×McIntyre	—×1	4	0	0
Do	Solanum sp. (S. A. No. 68)×McIntyre	A×1	2	2	100
Do	Solanum sp. (S. A. No. 69)×McIntyre	—×1	4	0	0
Do	Solanum sp. (S. A. No. 72)×McIntyre	—×1	3	0	0
	Total and average	....	252	81	32.14
Aug. 3, 1914	Dibble's Russet×Norcross	A×—	19	2	10.53
July 28, 1916	Garnet Chili×Norcross	A×—	11	0	0
July 27, 1916	Green Mountain×Norcross	A×—	37	0	0
July 28, 1916	McCormick×Norcross	A×—	12	8	66.67
July 27, 1916	McIntyre×Norcross	A×—	20	0	0
July 28, 1916	Round Pinkeye×Norcross	....	9	0	0
July 28, 1916	Up-to-Date×Norcross	....	37	0	0
	Total and average	....	145	10	6.90
Aug. 10, 1914	British Queen×Petronius	B×1	10	0	0
Do	Carman No. 3×Petronius	A×1	12	9	75.00
Aug. 8, 1914	Charles Downing×Petronius	B×1	12	0	0
Aug. 6, 1917	Congo×Petronius	—×1	2	0	0
Aug. 5, 1917	Doma (S. A. No. 18)×Petronius	—×1	4	0	0
Aug. 10, 1915	Early Rockford×Petronius	A×1	20	8	40.00
July 28, 1916	Early Rose×Petronius	A×1	4	2	50.00
Aug. 5, 1917	Francesca Colorada (S. A. No. 86)×Petronius	A×1	19	15	78.95
July 28, 1916	Garnet Chili×Petronius	A×1	15	0	0
Aug. 9, 1915	Green Mountain×Petronius	A×1	31	9	29.03
Aug. 6, 1917	....do	A×1	13	5	38.46
Aug. 12, 1915	Irish Cobbler×Petronius	A×1	262	85	32.44
July 29, 1916	.....do	A×1	81	40	49.38
Aug. 10, 1915	Manila×Petronius	A×1	53	26	49.06
Aug. 10, 1914	McCormick×Petronius	A×1	16	5	31.25
Do	Non Blight×Petronius	A×1	23	20	86.96
July 28, 1916	Perfect Peachblow×Petronius	—×1	29	0	0
Aug. 5, 1917	Picun Negra (S. A. No. 52)×Petronius	—×1	3	3	100
Aug. 10, 1915	President Roosevelt×Petronius	A×1	46	0	0
Aug. 10, 1914	Prosperity×Petronius	A×1	9	3	33.33
Aug. 8, 1914	Radium×Petronius	—×1	25	5	20.00
Aug. 3, 1915	Rural New Yorker×Petronius	A×1	34	18	52.94

TABLE 1.—*Potato crosses grouped according to pollen parent recorded by the United States Department of Agriculture during the 9-year period from 1914 to 1922, inclusive*—Continued.

Date of crossing.	Parents.	Classes involved in cross.	Number of— Flowers crossed.	Number of— Seed balls produced.	Percentage of success.
Aug. 6, 1917	Russet Rural×Petronius	A×1	3	2	66.67
Aug. 8, 1914	Rust Proof×Petronius	—×1	7	0	0
Aug. 10, 1914	Sir Walter Raleigh×Petronius	A×1	15	13	86.67
Aug. 6, 1917	.....do	A×1	8	1	12.50
Aug. 5, 1917	Solanum sp. (S. A. No. 24)×Petronius	A×1	3	3	100
Do	Solanum sp. (S. A. No. 37)×Petronius	—×1	3	0	0
Do	Solanum sp. (S. A. No. 69)×Petronius	—×1	3	1	33.33
Do	Solanum sp. (S. A. No. 72)×Petronius	—×1	3	0	0
Do	Solanum sp. (S. A. No. 92)×Petronius	—×1	3	0	0
Aug. 6, 1917	Solanum sp. (S. A. No. 148)×Petronius	—×1	8	0	0
Do	Solanum sp. (S. A. No. 152)×Petronius	—×1	3	0	0
Aug. 8, 1914	State of Maine×Petronius	—×1	5	0	0
Aug. 6, 1917	Tuquerrena Blanca (S. A. No. 182)×Petronius	—×1	1	0	0
Aug. 11, 1915	White McCormick×Petronius	A×1	6	5	83.33
July 28, 1916	Yellow-fleshed variety×Petronius	—×1	5	0	0
	Total and average		799	278	34.79
Aug. 7, 1914	American Wonder×Pojata		19	0	0
Do	Beauty of Hebron×Pojata	A×—	13	3	23.08
Do	Early Vicktor×Pojata		6	1	16.67
Aug. 8, 1914	Farmer×Pojata		11	0	0
Do	Gold Coin×Pojata	A×—	14	0	0
Aug. 7, 1914	Irsh Cobbler×Pojata	A×—	9	1	11.11
Aug. 8, 1914	Late Blightless×Pojata	A×—	7	0	0
Do	McKinley×Pojata		10	0	0
Aug. 7, 1914	New Scotch Rose×Pojata	A×—	10	0	0
Do	Seneca Beauty×Pojata	A×—	14	0	0
Do	White Beauty×Pojata		8	0	0
Do	White Elephant×Pojata	A×—	15	4	26.67
	Total and average		136	9	6.62
Aug. 7, 1914	Early Eureka × Potentat		4	0	0
Do.	Early Michigan × Potentat	A×—	4	0	0
Aug. 8, 1914	Farmer × Potentat		10	0	0
Do.	Green Mountain × Potentat	A×—	4	0	0
Aug. 7, 1914	Irish Cobbler × Potentat	A×—	3	0	0
Do.	Seneca Beauty × Potentat	A×—	10	0	0
	Total and average		35	0	0
July 22, 1919	Black Christy × Seedling 14232	B×—	17	4	23.53
July 21, 1919	Seedling 24642 × Seedling 14232		75	0	0
July 29, 1919	Seedling 38774 × Seedling 14232	A×—	6	4	66.67
	Total and average		98	8	8.16
July 9, 1921	America × Seedling 24642	A×1	4	2	50.00
July 19, 1922	Arran Rose × Seedling 24642	A×1	23	6	26.09
July 22, 1919	Black Christy × Seedling 24642	B×1	22	2	9.09
July 26, 1920	.....do	B×1	9	2	22.22
July 23, 1920	British Queen × Seedling 24642	B×1	45	3	6.67
July 12, 1922	Charles Downing × Seedling 24642	B×1	20	1	5.00
July 17, 1922	.....do	B×1	44	3	6.82
July 22, 1919	Clio × Seedling 24642	A×1	40	24	60.00
July 14, 1921	.....do	A×1	11	0	0
July 18, 1921	.....do	A×1	12	0	0
July 15, 1921	.....do	A×1	13	0	0
July 30, 1921	.....do	A×1	5	1	20.00
July 20, 1920	Cummings' Pride × Seedling 2 642	B×1	6	1	16.67
July 23, 1920	Dargill Early×Seedling 24642	A×1	8	2	25.00
July 14, 1921	Early Ohio×Seedling 24642	A×1	27	0	0
July 16, 1921	.....do	A×1	16	0	0
July 26, 1921	.....do	A×1	18	1	5.56
Aug. 1, 1921	.....do	A×1	10	8	80.00
July 22, 1922	.....do	A×1	38	31	81.58
May 27, 1922	Early Rose×Seedling 24642	A×1	1	0	0
May 29, 1922	.....do	A×1	11	0	0
May 31, 1922	.....do	A×1	4	0	0
June 5, 1922	.....do	A×1	14	1	7.14
July 14, 1922	.....do	A×1	23	18	78.26
July 17, 1922	.....do	A×1	86	82	95.35
July 22, 1920	Edzell Blue×Seedling 24642	A×1	41	21	51.22
July 23, 1920	Epicure×Seedling 24642	A×1	7	0	0
July 12, 1922	.....do	A×1	20	2	10.00

TABLE 1.—*Potato crosses grouped according to pollen parent recorded by the United States Department of Agriculture during the 9-year period from 1914 to 1922, inclusive*—Continued.

Date of crossing.	Parents.	Classes involved in cross.	Number of— Flowers crossed.	Number of— Seed balls produced.	Percentage of success.
July 24, 1922	Factor×Seedling 24642	B×1	27	0	0
July 24, 1920	Irish Cobbler×Seedling 24642	A×1	108	50	46.30
July 28, 1920	McCormick×Seedling 24642	A×1	42	4	9.52
June 5, 1922	McIntyre×Seedling 24642	A×1	4	0	0
June 7, 1922	....do	A×1	4	0	0
July 13, 1922	Papa Chaucha (S. A. No. 327)×Seedling 24642	A×1	5	3	60.00
July 19, 1922	....do	A×1	3	0	0
Aug. 2, 1920	Russet Rural×Seedling 24642	A×1	37	19	51.35
July 22, 1919	Seedling 11844×Seedling 24642	A×1	48	0	0
July 17, 1920	....do	A×1	44	21	47.73
July 22, 1919	Seedling 38774×Seedling 24642	A×1	37	10	27.03
July 22, 1920	Seedling 40043×Seedling 24642	A×1	19	9	47.37
July 20, 1920	Seedling 40108×Seedling 24642	A×1	21	14	66.67
Do	Seedling 40238×Seedling 24642	A×1	41	33	80.49
July 21, 1922	Seedling 40568×Seedling 24642	A×1	47	36	76.60
July 20, 1922	Seedling 41420×Seedling 24642	—×1	14	2	14.29
Do	Seedling 41462×Seedling 24642	—×1	49	1	2.04
July 13, 1922	Seedling 41639×Seedling 24642	—×1	6	0	0
Do	Seedling 41701×Seedling 24642	A×1	33	9	27.27
July 12, 1922	Seedling 41704×Seedling 24642	—×1	16	4	25.00
July 19, 1922	....do	—×1	12	0	0
July 18, 1822	Seedling 41772×Seedling 24642	—×1	2	0	0
July 20, 1922	....do	—×1	2	0	0
July 21, 1922	Seedling 41893×Seedling 24642	A×1	25	17	68.00
July 29, 1920	Seedling 9–1×Seedling 24642	A×1	28	14	50.00
July 26, 1920	Seedling 9–11×Seedling 24642	A×1	33	10	30.30
July 24, 1920	Seedling 9–12×Seedling 24642	A×1	32	2	6.25
Do	Seedling 9–13×Seedling 24642	A×1	42	7	16.67
July 21, 1922	SeedlingX45 (1920)×Seedling 24642	A×1	19	16	84.21
July 21, 1920	Sharpe's Express×Seedling 24642	A×1	13	5	38.46
July 25, 1921	Solanum sp. (Mexico)×Seedling 24642	A×1	5	0	0
July 16, 1920	Triumph×Seedling 24642	B×1	61	8	13.11
Aug. 5, 1920	Yellow-fleshed variety (from Costa Rica) ×Seedling 24642	A×1	34	2	5.88
	Total and average		1,491	507	34.00
July 7, 1922	Seedling 4240×Seedling 39117	A×1	2	0	0
July 10, 1922	....do	A×1	2	0	0
July 11, 1922	....do	A×1	4	0	0
July 26, 1922	....do	A×1	27	8	29.63
	Total and average		35	8	22.86
July 20, 1920	Charles Downing×Seedling 40108	B×1	16	7	43.75
July 18, 1921	Early Ohio×Seedling 40108	A×1	6	0	0
Aug. 3, 1921	....do	A×1	5	3	60.00
July 23, 1920	Seedling 40238×Seedling 40108	A×1	61	24	39.34
July 24, 1920	Seedling 9–13×Seedling 40108	A×1	46	0	0
Do	Triumph×Seedling 40108	B×1	9	2	22.22
	Total and average		143	36	25.17
June 20, 1921	American Giant×Seedling 40568	A×1	22	10	45.45
July 29, 1920	British Queen×Seedling 40568	B×1	19	0	0
July 24, 1922	Hamakua×Seedling 40568	A×1	57	33	57.89
June 7, 1922	McIntyre×Seedling 40568	A×1	4	4	100
June 9, 1922	....do	A×1	4	3	75.00
June 13, 1921	Rural New Yorker×Seedling 40568	A×1	22	8	36.36
Aug. 2, 1920	Russet Rural×Seedling 40568	A×1	30	14	46.67
June 17, 1922	Seedling 39117×Seedling 40568	A×1	4	4	100
June 23, 1921	Seedling 40768×Seedling 40568	A×1	13	1	7.69
	Total and average		175	77	44
Aug. 8, 1914	Farmer×Senator		9	0	0
Do	Freeman×Senator		5	0	0
Do	Gold Coin×Senator	A×—	8	4	50.00
Do	Green Mountain×Senator	A×—	4	0	0
Do	Late Blightless×Senator	A×—	5	0	0
Do	McKinley×Senator		3	0	0
Do	Norcross×Senator	A×—	19	1	5.26
	Total and average		53	5	9.43

TABLE 1.—*Potato crosses grouped according to pollen parent recorded by the United States Department of Agriculture during the 9-year period from 1914 to 1922, inclusive*—Continued.

Date of crossing.	Parents.	Classes involved in cross.	Number of— Flowers crossed.	Seed balls produced.	Percentage of success.
Aug. 5, 1917	Francesca Colorada (S. A. No. 86)×Switez	A×1	11	0	0
Aug. 8, 1914	Radium×Switez	—×1	5	0	0
Do	Rust Proof×Switez	—×1	10	0	0
Aug. 5, 1917	Solanum sp. (S. A. No. 37)×Switez	—×1	4	1	25.00
Do	Solanum sp. (S. A. No. 48)×Switez	—×1	3	0	0
Do	Solanum sp. (S. A. No. 69)×Switez	—×1	4	0	0
	Total and average		37	1	2.70
Aug. 7, 1914	Early Eureka×Triumph	—×3	7	0	0
Do	Early Standard (Dreer's)×Triumph	—×3	5	0	0
	Total and average		12	0	0
Aug. 7, 1914	Early Michigan×Venezuela	A×—	3	0	0
Do	Garnet Chili×Venezuela	A×—	6	0	0
	Total and average		9	0	0
July 27, 1916	Up-to-Date×White Albino (Acc. No. 19393)	—×3	51	0	0
Aug. 10, 1914	British Queen×Zbyszek	B×1	12	0	0
Do	Late Vicktor×Zbyszek	A×1	10	8	80.00
Do	McCormick×Zbyszek	A×1	8	1	12.50
Do	Non Blight×Zbyszek	A×1	10	8	80.00
Do	Prosperity×Zbyszek	A×1	10	6	60.00
Do	Rural New Yorker×Zbyszek	A×1	7	2	28.57
	Total and average		57	25	43.86

The results for 10 varieties whose records show good seed production (class A) are brought together in Table 2, the data being arranged according to the class in which the male parent belongs with respect to the quality of its pollen.

These 10 varieties produced seed balls in 40 per cent of the flowers crossed with pollen of class 1, in 13 per cent of the flowers crossed with pollen of class 2, and no fruit for 155 flowers crossed with pollen of class 3.

It appears that some varieties have produced seed balls rather feebly even when the best pollen has been used. The data for four such varieties which have been placed in class B are also assembled in Table 2. Of the total of 305 flowers crossed with pollen of class 1, only 8 per cent produced seed balls.

Several of the varieties listed in class B are known to be poor flower producers, even at Presque Isle. Few flowers open and the early abscission of these is marked. This suggests that the feeble production of fruits by such varieties is directly limited by this condition and possibly can be changed by growing these varieties under conditions which decrease abscission and favor abundant blooming. Varieties in class A blooming at the New York Botanical Garden are lower in fruit production than at Presque Isle, giving more failures to self and cross pollinations with pollen of class 1. Comparative tests of pollen of the Clio, McCormick, McIntyre, and Seedling 24642 varieties growing in both localities were made in 1922. There appeared to be no appreciable difference in quantities of pollen or in its viability, but the same combinations which were most

successful at Presque Isle were much less effective at the New York Botanical Garden, evidently due to the differences in blooming and abscission.

TABLE 2.—*Typical results for varieties of potatoes classed as A and B with respect to ability to produce fruit, crossed with varieties placed in classes 1, 2, and 3, respectively, with regard to the quality of their pollen.*

Varieties crossed.	Grade of pollen of male parent.					
	Class 1.		Class 2.		Class 3.	
	Number of flowers crossed.	Number of seed balls.	Number of flowers crossed.	Number of seed balls.	Number of flowers crossed.	Number of seed balls.
CLASS A VARIETIES.						
Beauty of Hebron×Busola	9	7				
Beauty of Hebron×Green Mountain			10	5		
Beauty of Hebron×Cedon					11	0
Clio×Keeper	11	5				
Clio×McCormick	26	5				
Clio×Seedling 24642	81	25				
Clio×Seedling 38774					8	0
Country Gentleman×Busola	8	5				
Country Gentleman×Green Mountain			21	4		
Country Gentleman×Country Gentleman					3	0
Country Gentleman×Irish Cobbler					4	0
Early Michigan×Busola	8	7				
Early Michigan×Green Mountain			12	0		
Early Michigan×Early Petoskey					7	0
Early Michigan×Irish Cobbler					14	0
Early Rose×Busola	19	14				
Early Rose×Petronius	4	2				
Early Rose×Seedling 24642	139	101				
Early Rose×Garnet Chili			30	0		
Early Rose×Early Petoskey					4	0
Early Rose×Early Rose					7	0
Garnet Chili×Busola	24	10				
Garnet Chili×McIntyre	33	0				
Garnet Chili×Petronius	15	0				
Garnet Chili×Green Mountain			15	0		
Garnet Chili×Early Rose					37	0
Green Mountain×Busola	110	37				
Green Mountain×Cacha Negra (S. A. No. 7)	48	9				
Green Mountain×McCormick	248	15				
Green Mountain×Petronius	44	14				
Green Mountain×Gold Coin			61	0		
Green Mountain×Green Mountain			115	2		
Green Mountain×Seedling 18714	15	0				
Green Mountain×Beauty of Hebron					18	0
Green Mountain×Cedon					29	0
Irish Cobbler×Busola	441	211				
Irish Cobbler×McCormick	91	46				
Irish Cobbler×Petronius	343	125				
Irish Cobbler×Seedling 24642	108	50				
Irish Cobbler×Cedon					8	0
Irish Cobbler×Early Petoskey					5	0
McCormick×Busola	89	62				
McCormick×Petronius	16	5				
McCormick×Seedling 24642	42	4				
McCormick×Green Mountain			44	27		
Rural New Yorker×Busola	49	35				
Rural New Yorker×Petronius	34	18				
Rural New Yorker×Seedling 40568	22	8				
Rural New Yorker×Zbyszek	7	2				
Rural New Yorker×Green Mountain			50	10		

TABLE 2.—*Typical results for varieties of potatoes classed as A and B with respect to ability to produce fruit, crossed with varieties placed in classes 1, 2, and 3, respectively, with regard to the quality of their pollen*—Continued.

Varieties crossed.	Grade of pollen of male parent.					
	Class 1.		Class 2.		Class 3.	
	Number of flowers crossed.	Number of seed balls.	Number of flowers crossed.	Number of seed balls.	Number of flowers crossed.	Number of seed balls.
CLASS B VARIETIES.						
British Queen×Bohun	16	0				
British Queen×Busola	12	0				
British Queen×Petronius	10	0				
British Queen×Zbyszek	12	0				
British Queen×Seedling 24642	45	3				
British Queen×Seedling 40568	19	0				
Charles Downing×Busola	6	0				
Charles Downing×Petronius	12	0				
Charles Downing×Seedling 24642	64	4				
Charles Downing×Seedling 40108	16	7				
Cummings' Pride×Clio	17	0				
Cummings' Pride×Seedling 24642	6	1				
Triumph×Seedling 24642	61	8				
Triumph×Seedling 40108	9	2				
Triumph×Early Standard (Dreer's)			21	0		
Triumph×Early Petoskey					7	0
Triumph×Irish Cobbler					25	0

The classification of the various varieties and seedlings studied, both in regard to the condition of anthers and of pollen (classes 1, 2, 3, and 4) and with respect to ability to produce fruit (classes A, B, C, and D) is given in Table 3.

Under the conditions at Presque Isle, where flowers are produced in abundance, most varieties, if not all of them, are able to function as seed parents when properly pollinated with viable pollen. This is well shown by the very unusual development of fruit in those varieties and seedlings having considerable viable pollen. Of the 588 seedlings of the 1921 sowing kept in 1922 and planted in five-hill units, 81 produced seed balls to open pollination. Of the 188 seedlings of previous years grown in 1922, 56 were producing seed balls, and for one of these, No. 39477, the fruits were especially abundant (Pl. VIII, fig. 1). The pollen of many of these which produced fruit was tested, and in every case it was found to be in class 1 (Pl. V, fig. 2). A few varieties seem low in ability to produce fruit (class B), but according to present data none are to be placed in class C as entirely unable to produce fruit.

Evidence of a parthenocarpic development of fruits has been found in 14 varieties, including Rose No. 4 and most members of the Burbank and Rural groups. At the time of the opening of the flowers, the ovaries of many pistils are decidedly enlarged and the anthers and corollas before they wither are pushed forward and to one side by the rapidly enlarging ovaries (Pl. VII, fig. 1). Such fruits seldom, if ever, contain seeds (Pl. VII, fig. 2). They may reach a good size, but usually fall before they are fully ripe. Several of the varieties exhibiting this tendency are known to be good seed producers when

viable pollen is used. The tendency to parthenocarpy, however, has not thus far been observed in any plant having considerable viable pollen. To determine the size which fruits of this type attain, 100 seed balls were collected in 1922 from between the rows of varieties belonging to the Rural group. At this time (August 22) practically all of the seed balls on these varieties had dropped off. The diameters ranged from 7 to 16 millimeters, averaging 11.66 millimeters. None of these fruits contained seeds.

TABLE 3.—*List of potato varieties studied, showing the class to which each is assigned with respect to the condition of its anthers and pollen and to its ability to produce seed balls.*

[A roman numeral in parentheses after the varietal name indicates the group to which the variety thus marked has been referred according to the classification of Stuart (23) and of the Committee on Varietal Nomenclature and Testing, Potato Association of America (25). An asterisk (*) indicates that the pollen of the variety thus marked was tested for two seasons. A single plus sign (+) indicates that the variety is a little better with respect to condition of anthers and pollen or with respect to ability to produce seed balls than the standard for the class in which it has been placed. The double plus signs (++) indicate an abundance of viable pollen, or prolific production of seed balls. The minus sign (−) indicates that the variety is below standard, but not low enough to place in the next lower class. The use of the question mark (?) denotes an uncertain status. While work thus far has not shown any evidence that the variety can produce seed balls, it is possible that further efforts may prove successful. The method of pollination on which the conclusions in columns A to D are based is indicated by circled figures as follows: ①=Controlled pollination by hand, ②=natural fertilization in the field, ③=both controlled and natural pollination.]

Variety or species.	Source.	Class with respect to—							
		Condition of anthers and pollen.				Ability to produce seed balls.			
		1	2	3	4	A	B	C	D
North American, European, and miscellaneous varieties:									
Ally	Great Britain			3					
America	do			3		A①			
American Giant (VIII)	United States			3		A①			
Australian Blue				3		A①			
Axtell's Early (I)	United States			3					
Beats-Them-All (VI)	do			3					
Beauty of Hebron (VI)	do			3		A①			
Berrick	Great Britain				4				
Bishop	do			3					
Bohun	Poland	1							
Bountiful (VIII)			2						
British Queen	Great Britain			3			B①		
Brown Beauty (IV)	Prince Edward Island				4				
Burbank (VII)	United States				4				D
Busola	Poland	*1				A③			
California Russet (VII)	United States				4				D
Carman No. 1 (VIII)	do			*3					
Carman No. 3 (IX)	do			3		A①			
Caseker Salathornschen	Germany (?)		2			A①			
Charles Downing (III)	United States				4		B①		
Clio	Germany	*1−				A③			
Condon's Early Snowflake (I)	United States			3					
Country Gentleman (VIII)	do			3		A①			
Cummings' Pride (XII)					4		B①		
Delaware (VIII)	United States			3					
Deposit Wonder	do			3		A②			
Earliest-of-All [1] (III)	do				4				
Early Eureka (I)	do				4				
Early Harvest (III)	do				4				
Early Ohio (V)	do			*3		A①			
Early Petoskey (I)	do			3					
Early Rose (IV)	do			*3		A①			
Early Standard (Dreer's) (I)	do		2						
Early Sunrise (IV)	do			3					
Early Victory	do				4+				
Eclipse	Great Britain				4+				
Edinburgh Castle	do				4				
Ehnola (III)	United States				4				
Eldorado	Great Britain				4				

[1] This variety represents the type of Earliest-of-All which is grown in the State of Washington and is distinct from the Irish Cobbler stock, to which this name is sometimes applied.

TABLE 3.—*List of potato varieties studied, showing the class to which each is assigned with respect to the condition of its anthers and pollen and to its ability to produce seed balls*—Continued.

Variety or species.	Source.	Class with respect to—							
		Condition of anthers and pollen.				Ability to produce seed balls.			
		1	2	3	4	A	B	C	D
North American, European, and miscellaneous varieties—Continued.									
Evergreen	United States			*3		A①			
Factor (XII)	Great Britain			3			B①		
Farmer (VIII)	United States		2						
Favorite	Great Britain			3					
Garnet Chili	United States		2+			A①			
Gold Coin (VIII)	do.		*2–			A①			
Golden Rule (IX)	do.			3					D
Golden Wonder	Great Britain			3–					
Great Scott	do.				4				
Green Mountain (VIII)	United States		*2			A③			
Gurney's Bugless (VIII)	do.		2						
Hamakua	Hawaii			*3–		A①			
Heavyweight (IX)	United States			3					
Irish Cobbler (I)	do.			*3		A①			
June Ripe (VIII)	do.			3					
Keeper	do.	*1				A③			
Kerr's Pink	Great Britain			3					
King George	do.			*3					
King of the Russets (IX)	United States			3					D
Langworthy	Great Britain			3					
Lochar	do.			3–					
Majestic	do.		2						
Martin's Horn		1–							
McCormick (XI)	United States	*1				A③			
McIntyre	Canada	*1				A③			
New Itasca (VIII)	United States		2						
New Queen (VI)	do.			3					
Nithsdale	Great Britain			3					
Non Blight (IX)	United States			3		A①			D
Olds' White Beauty (IX)	do.				4+				D
Oregon White Rose [2] (XII)				3					
Pan American (IX)	United States				4	A①			D
Pearl of Cannon Valley (IX)	do.			3–					D
Perfect Peachblow (XI)	do.				4+				
Portuguese Purple			*2						
Producer (XII)				3					
Rector	Great Britain		2+						
Rose No. 4 (IV)	United States				4+	A①			D
Round Pinkeye	do.			3					
Royal Russet (IX)	do.				4				D
Rural New Yorker No. 2 (IX)	do.			3–		A①			D
Russet Burbank (VII)	do.				4				D
Russet Rural (IX)	do.			*3–		A①			D
Sensation [3] (IX)	do.				4				D
Shamrock	Great Britain	1							
Sir Walter Raleigh (IX)	United States			*3		A①			
Solanum sp	China			3		A①			
....Do	Mexico			*3		A③			
Solanum tuberosum	Philippines			3					
Superba Irish (XII)				3					
Switez	Poland	1				A②			
Templar	Great Britain			3					
Tinwald Perfection	do.			3–					
Triumph (II)	United States			*3			B①		
Up-to-date (XII)	Great Britain			3					
Ursus	Poland			2?					
Vick's Improved No. 9 (IX)	United States			3					
Wellington (XII)				3					
White Albino	United States			3					
White Australian			2						
White City	Great Britain				4				
White Ohio (V)	United States			3					
White Rose (IV)	do.			*3					
Witch Hill	Great Britain			3–					

[2] This variety is incorrectly named. It appears to be identical with Up-to-Date rather than White Rose.
[3] The stock grown in Maine under this name belongs to the Rural group and is evidently distinct from the Sensation referred to the Green Mountain group in the report of the Committee on Varietal Nomenclature and Testing. (*25*).

TABLE 3.—*List of potato varieties studied, showing the class to which each is assigned with respect to the condition of its anthers and pollen and to its ability to produce seed balls*—Continued.

Variety or species.	Source.	Class with respect to— Condition of anthers and pollen. 1	2	3	4	Ability to produce seed balls. A	B	C	D
North American, European, and miscellaneous varieties—Continued.									
Wohltmann	Germany			3					
Yellow-fleshed variety	Costa Rica			3		A①			
Zbyszek	Poland	1							
South American varieties:									
Cacha Blanca (S. A. No. 8)	Chile		2			A①			
Cacha Negra (S. A. No. 7)	do	*1				A③			
Caiceda (S. A. No. 301)	Colombia	1				A②			
Criolla (S. A. No. 302)	do	1							
Cueruda Morada (S. A. No. 319)	Ecuador	1+				A②			
Domminga (S. A. No. 309)	do	1				A②			
Leche (S. A. No. 323)	do	1+				A②			
Leona (S. A. No. 312)	do	1				A②			
Leona Pazmina (S. A. No. 313)	do		2			A②			
Manzana (S. A. No. 314)	do		2−			A②			
Margarita (S. A. No. 320)	do		2			A②			
Morada (S. A. No. 318)	do	1+				A②			
Papa Chaucha (S. A. No. 327)	do	1				A③			
Picun Negra (S. A. No. 52)	Chile			3					
Solanum sp. (S. A. No. 4)					4				
Solanum sp. (S. A. No. 10)	Chile				4				
Solanum sp. (S. A. No. 19)	do			3					
Solanum sp. (S. A. No. 21)	Bolivia			3					
Solanum sp. (S. A. No. 24)	do			3		A②			
Solanum sp. (S. A. No. 128)	do		2			A②			
Tabla (S. A. No. 315)	Ecuador	1				A②			
Unknown variety (S. A. No. 303)	Colombia	1				A②			
Unknown variety (S. A. No. 304)	do		2			A②			
Unknown variety (S. A. No. 307)	do		2			A②			
Villaroela (S. A. No. 9)	Chile		2			A②			
Yungara (S. A. No. 316)	Ecuador	1				A②			
Yungara (S.A. No. 324)	do	1				A②			
U. S. D. A. seedlings:									
No. 4240	United States				4	A①			
No. 11844	do	1				A①			
No. 17042	do			3					
No. 18714	do	1				A③			
No. 24642	do	1					B①		
No. 37662	do			3		A①			
No. 38774	do			3		A①			
No. 38816	do		2			A−②			
No. 38946	do	1				A−②			
No. 38967	do			3					
No. 38988	do			3					
No. 39117	do	1				A②			
No. 39173	do		2−						
No. 39257	do			3					
No. 39285	do		2						
No. 39293	do				4				
No. 39370	do		2−			A−②			
No. 39477	do	*1				A+②			
No. 39981	do		2						
No. 40108	do	1				A①			
No. 40568	do	1				A③			
No. 40768	do	1−				A③			
No. 41001	do	1				A②			
No. 41019	do			3					
No. 41031	do			3					
No. 41116	do	1−				A②			
No. 41153	do			3					
No. 41156	do		2			A①			
No. 41197	do			3					
No. 41199	do			3					
No. 41206	do				4				
No. 41208	do			3					
No. 41235	do			3					
No. 41236	do			3					
No. 41242	do			3					
No. 41245	do			3					
No. 41249	do			3					
No. 41251	do			3					

TABLE 3.—*List of potato varieties studied, showing the class to which each is assigned with respect to the condition of its anthers and pollen and to its ability to produce seed balls*—Continued.

Variety or species.	Source.	Class with respect to— Condition of anthers and pollen. 1	2	3	4	Ability to produce seed balls. A	B	C	D
U. S. D. A. seedlings—Continued.									
No. 41361	United States		2			A①			
No. 41366	do			3					
No. 41372	do		2						
No. 41373	do	1–				A–②			
No. 41375	do	1							
No. 41376	do			3					
No. 41378	do	1–				A–②			
No. 41382	do	1							
No. 41384	do	1–				A–②			
No. 41396	do				4				
No. 41582	do	1+				A②			
No. 41694	do	1				A–②			
No. 41703	do	1				A–②			
No. 41720	do	1				A②			
No. 41725	do	1				A②			
No. 41931	do	1				A②			
No. 41932	do	1				A–②			
No. 41933	do	1+				A②			
No. 41934	do	1				A②			
No. 41935	do	1+				A②			
M. S. –1	do	1				A③			
×45 (1920)	do	1				A③			
No. 7–10	do	1				A②			
No. 7–15	do	1				A③			
No. 9–3	do		2						
No. 9–11	do	1				A③			
No. 9–12	do	1				A③			
No. 9–13	do		2						
No. 35–28	do	1							
No. 35–57	do	1–							
No. 78–20	do	1				A②			
No. 131–11	do		2			A+②			
No. 13858–1–18	do	1				A③			
Alaska seedlings:									
Edith (A–705)	Alaska			3					
Jane (A–1001)	do			3					
Jean (A–1066)	do			3					
Jill (A–1014)	do			3					
Josephine (A–1050)	do			3					
Judith (A–1053)	do			3					
June (A–1088)	do		2						
Wild species:									
Solanum chacoense No. 1	Paraguay	1++							
Solanum chacoense No. 2	do	1++							
Solanum chacoense No. 29	do	1++							
Solanum chacoense No. 50	do	1++							
Solanum fendleri No. 3[4]	United States	1+							
Solanum fendleri No. 14	do	1+							
Solanum fendleri No. 21	do	1+							
Solanum fendleri No. 24	do	1+							
Solanum fendleri No. 25	do	1+							
Solanum fendleri No. 35	do	1+							
Solanum fendleri No. 40	do	1+							
Solanum fendleri No. 53	do	1+							
Solanum fendleri No. 54	do	1+							
Solanum fendleri No. 59	do	1+							
Solanum fendleri No. 2–1	do	1+				A①			
Solanum fendleri No. 2–2	do	1+				A①			
Solanum fendleri No. 2–3	do	1+							
Solanum fendleri No. 2–4	do	1+							
Solanum fendleri No. 2–5	do	1+							
Solanum fendleri No. 2–6	do	1+				A①			
Solanum fendleri No. 2–7	do	1+							
Solanum fendleri No. 2–8	do	1+				A①			
Solanum fendleri No. 2–11	do	1+				A①			
Solanum fendleri No. 2–12	do	1+				A①			
Solanum fendleri No. 2–14	do	1+							
Solanum fendleri No. 11–1	do	1+							

[4] Numbers 3 to 59 were grown in the field, 2–1 to 11–15 in the greenhouse.

TABLE 3.—*List of potato varieties studied, showing the class to which each is assigned with respect to the condition of its anthers and pollen and to its ability to produce seed balls*—Continued.

Variety or species.	Source.	Class with respect to—							
		Condition of anthers and pollen.				Ability to produce seed balls.			
		1	2	3	4	A	B	C	D
Wild species—Continued.									
Solanum fendleri No. 11-4	United States	1+							
Solanum fendleri No. 11-5	do	1+							
Solanum fendleri No. 11-6	do	1+							
Solanum fendleri No. 11-7	do	1+				A1			
Solanum fendleri No. 11-8	do	1+							
Solanum fendleri No. 11-10	do	1+							
Solanum fendleri No. 11-12	do	1+							
Solanum fendleri No. 11-13	do	1+							
Solanum fendleri No. 11-14	do	1+				A1			
Solanum fendleri No. 11-15	do	1+							
Solanum jamesii No. 1-1	do			3					
Solanum jamesii No. 2-9	do	1+							
Solanum jamesii No. 3-7	do	1+							
Solanum jamesii No. 4-1	do	1							
Solanum jamesii No. 4-2	do	1				A1			
Solanum jamesii No. 4-4	do	1+							
Solanum jamesii No. 15	do	1+				A1			
Solanum jamesii No. 16	do	1+							
Solanum jamesii No. 17	do	1+				A1			
Solanum jamesii No. 19	do	1+							
Solanum jamesii No. 20	do	1+							
Solanum jamesii No. 21	do	1+							
Solanum jamesii No. 23	do	1+							
Solanum jamesii No. 24	do	1+							
Solanum jamesii No. 25	do	1+							
Solanum jamesii No. 26	do	1+							
Solanum jamesii No. 27	do	1+							
Solanum jamesii No. 28	do	1+							
Solanum jamesii No. 29	do	1+							
Solanum jamesii No. 30	do	1+				A1			
Solanum jamesii No. 31	do	1+				A1			
Solanum maglia No. 1-1-1	Peru		2						
Solanum maglia No. 1-3-1	do		2–						
Solanum maglia No. 1-1-2	do		2						
Solanum maglia No. 2-1-2	do		2–						
Solanum maglia No. 2-1-3	do		2–						
S. fendleri×S. chacoense (F_1 hybrid).	United States			3					
Nos. 126-1, 126-2	do			3					
Nos. 126-3, 126-5	do			3					
Nos. 126-7, 126-8	do			3					
Nos. 126-9, 126-10	do			3					
Nos. 126-11, 126-12	do			3					
Nos. 126-13, 126-17	do			3					
Nos. 126-18, 126-19	do			3					
Nos. 126-21, 126-22	do			3					
Nos. 126-24, 126-26	do			3					
Nos. 126-29, 126-30	do			3					
Nos. 126-33, 126-34	do			3					
Nos. 126-35, 126-36	do			3					
Nos. 126-38	do			3					
Nos. 126-40, 126-43	do			3					
Nos. 126-50, 127-2	do			3					

STERILITY IN HYBRIDS.

The only known hybrids between species of potatoes which up to the present time have been studied for impotence are the first-generation plants of a cross between *Solanum fendleri* and *S. chacoense* grown at Presque Isle in 1922. These hybrids bloomed abundantly; the anthers were well formed, fully colored, normally dehiscent, and the pollen abundant. From one to six tests for germination of pollen for each of 29 plants were made, involving many thousands of grains. Plump pollen grains were very few in number, and only five short pollen tubes were seen. Tests of the pollen of the parent species at

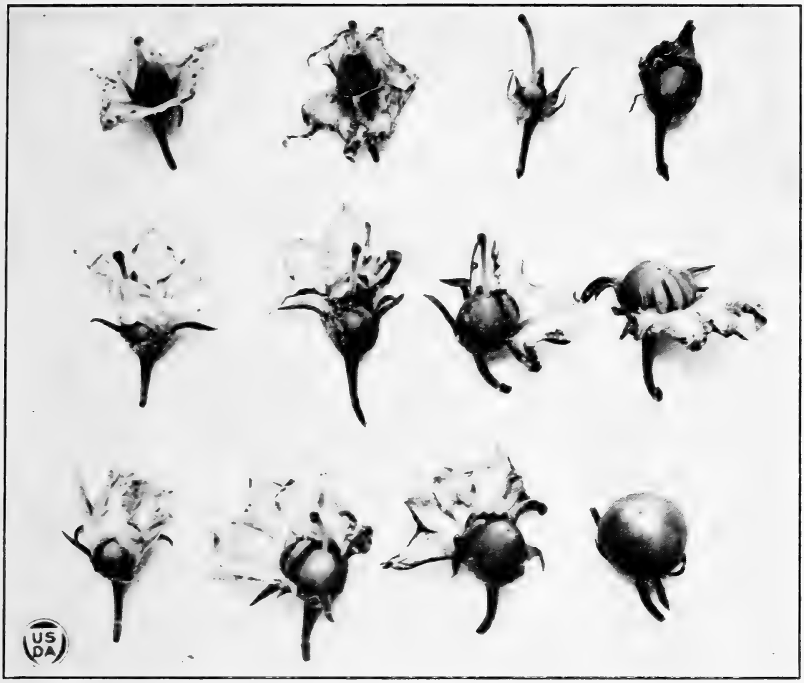


FIG. 1.—POTATO FLOWERS, SHOWING EARLY DEVELOPMENT OF SEED BALLS.

Top row.—McCormick. From left to right: Old flower, very old withered corolla, small ovary, and small fruit, resulting from pollination. Middle and bottom rows.—Sensation and Pearl of Cannon Valley, respectively, showing early development of pistils into parthenocarpic fruits while stamens are still fresh.

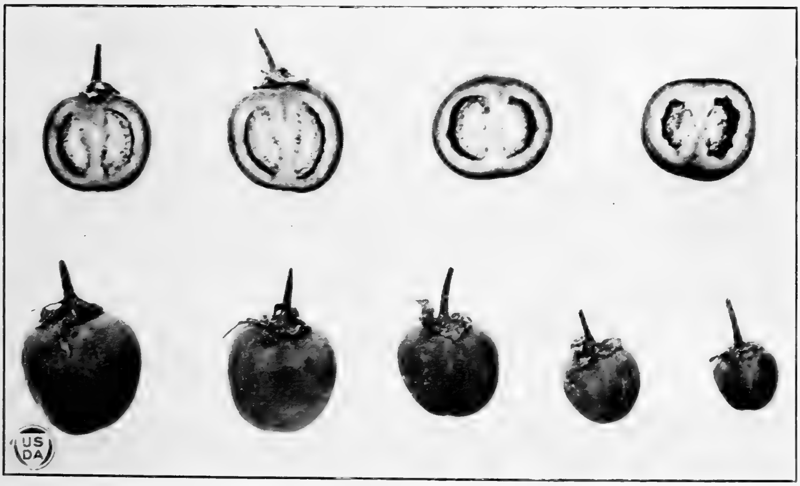


FIG. 2.—PARTHENOCARPIC FRUITS PRODUCED BY THE RURAL NEW YORKER POTATO.

FIG. 1.—GOOD SEED-BALL PRODUCTION IN RESPONSE TO OPEN POLLINATION IN SEEDLING 39477.

FIG. 2.—SOLANUM CHACOENSE, PLANT C-20.

Seed balls resulting from crossing with plant C-18 which is highly self-incompatible and also cross-incompatible to several plants. See Table 4.

the same time with the same media and in the same moist chamber gave the excellent germination characteristic of them. Flowers, 64 in number, representing 16 different plants, were inbred by pollinating with pollen from the same flower cluster. No evidence of seed-ball production was found. The results obtained from the germination and pollination studies indicate that a high degree of male sterility, possibly complete, exists in these hybrids.

When these hybrid plants were crossed with parent plants of *Solanum fendleri* failure resulted in every case, but fruit containing no seed was produced by several of the hybrids when *S. chacoense* was used as the pollen parent.

STERILITY FROM INCOMPATIBILITY.

INCOMPATIBILITIES IN CULTIVATED VARIETIES.

The data presented for cultivated varieties of potato by Taylor (*26*) and the discussions by Stuart (*24*) raise the question whether certain failures to set fruit, to cross, and to self-pollinate involve differences in compatibilities of fertilization or whether they merely involve impotence of either the pistil or the pollen. To be certain that incompatibilities exist one must be sure that the pollen and the pistils concerned are sufficiently potent to function in certain relations and that the pollinations are properly made. As pointed out in preceding pages, the cultivated varieties which completely fail to produce fruit to pollen known to be viable are indeed few, if any. It is clear that in respect to crosses between varieties the failures involve most frequently a parent which is impotent as a pollen parent or a parent somewhat feeble as a seed producer. When these grades of impotence are considered there appears to be no evidence of discriminating fertilizations or incompatibilities. The successes in crosses between varieties that are in class A, in regard to seed production, and those that are in class 1 in regard to potency of pollen, average about 40 per cent, a rather high average for plants which have such a decided tendency to the ready abscission of flowers.

The data from controlled pollinations are not sufficient to judge the self-compatibility of the varieties known to be both good seed producers and productive of viable pollen (classes A and 1), but it is such varieties and seedlings which often produce seed balls in abundance to open field pollination.

INCOMPATIBILITIES IN WILD SPECIES.

During the seasons of 1921 and 1922 a large number of hand pollinations were made for the purpose of determining whether incompatibilities exist in certain of the wild species and also to test cross compatibility between these species and between these and cultivated varieties. The work was started in 1921 with plants of three wild species, *Solanum chacoense*, *S. fendleri*, and *S. jamesii*, for all of which the pollen produced is highly potent. Most of the work was performed in the greenhouse, though a few plants in the field were used. The plants of *S. chacoense* and *S. jamesii* were grown from tubers. It is not known whether the seed tubers of the species first named were produced by one or by several plants. Those of the species last named were from a composite lot of several hills grown in the field the previous season. The plants of *S. fendleri* were grown from seed.

The flower clusters which were used for the pollination experiments were covered with paper sacks just before the first flowers were ready to open. Since the flowers of each cluster opened in succession it was necessary to inspect them at frequent intervals, usually every other day, and pollinate each as it reached the proper stage of maturity, which was considered to be when the terminal pores of the anthers were open ready for dehiscence. As a rule, where self-pollination was employed each flower was pollinated with its own pollen, but in a few instances, where pollen was scarce, that of another flower of the same cluster was used. In the tests for cross compatibilities pollen from another plant was used. The results are given in Tables 4, 5, and 6.

TABLE 4.—*Results of hand pollinations in Solanum chacoense, in 1921 and 1922.*

SELFED.

Plant.	Number of—		Plant.	Number of—	
	Flowers pollinated.	Seed balls.		Flowers pollinated.	Seed balls.
No. 1	8	0	No. 24	9	0
No. 2	17	0	No. 25	2	0
No. 3	8	0	No. 26	3	0
No. 7	4	0	No. 27	4	0
No. 8	7	0	No. 29	7	0
No. 10	5	0	No. 38	3	0
No. 12	8	0	No. 39	2	0
No. 15	7	0	No. 43	4	0
No. 18	9	0	No. 50	5	0
No. 19	5	0	No. 51	2	0
No. 21	8	0	No. 52	3	0

CROSSES BETWEEN DIFFERENT PLANTS WITHIN THE SPECIES.

Parents.	Number of—		Parents.	Number of—	
	Flowers crossed.	Seed balls.		Flowers crossed.	Seed balls.
No. 1 × No. 2	7	0	No. 13 × No. 29	6	0
No. 2 × No. 5	6	0	No. 14 × No. 5	2	0
No. 2 × No. 18	1	0	No. 17 × No. 21	2	0
No. 3 × No. 1	8	0	No. 18 × No. 1	12	0
No. 3 × No. 18	7	0	No. 18 × No. 2	5	0
No. 3 × No. 21	7	0	No. 20 × No. 18	6	6
No. 3 × No. 40	4	0	No. 22 × No. 26	2	0
No. 4 × No. 21	10	10	No. 29 × No. 1	4	0
No. 5 × No. 18	4	0	No. 29 × No. 2	5	0
No. 6 × No. 26	5	0	No. 44a × No. 18	9	0
No. 7 × No. 21	6	0	No. 45 × No. 3	2	0
No. 8 × No. 3	5	0	No. 47 × No. 29	2	2
No. 8 × No. 18	4	0	No. 50 × No. 2	1	0
No. 9 × No. 5	6	0	No. 50 × No. 18	1	0
No. 11 × No. 5	2	0	No. 50 × No. 26	6	0
No. 13 × No. 11	1	0	No. 50 × No. 29	5	0
No. 13 × No. 18	3	0	No. 51 × No. 26	2	0

Every one of the 22 selfed plants listed in Table 4 completely failed to produce seed balls. Of the 34 combinations in crosses only three were successful, and for these every pistil pollinated produced a seed ball with viable seeds. It is, of course, not known how many of these plants were of the same clon, and for only the three plants which set fruit was it shown that there is a full potency of pistils. The pollen of all plants available for study was highly potent (see Table 3). It appears, therefore, that there are both self-incompati-

bilities and cross-incompatibilities in this strain of *Solanum chacoense*. (See Pl. VIII, fig. 2.)

Table 5.—*Results of hand pollinations in Solanum fendleri, all selfed, in 1921 and 1922.*

Plant.	Number of—		Plant.	Number of—	
	Flowers pollinated.	Seed balls.		Flowers pollinated.	Seed balls.
No. 1	1	1	No. 2–6	2	1
No. 2	2	2	No. 2–8	14	7
No. 3	2	2	No. 2–9	10	3
No. 4	2	2	No. 2–10	2	2
No. 5	3	2	No. 2–11	3	1
No. 6	7	7	No. 2–12	3	1
No. 7	1	0	No. 2–13	2	1
No. 8	2	0	No. 11–3	8	5
No. 9	9	8	No. 11–7	8	1
No. 11	2	2	No. 11–9	6	4
No. 2–1	2	1	No. 11–11	7	5
No. 2–2	6	2	No. 11–14	5	5

Of the 24 plants of *Solanum fendleri* grown from seed and listed in Table 5, all but two produced seed balls to controlled self-pollinations. For the two plants that failed only 1 and 2 flowers, respectively, were selfed, so the failures for this may be due to experimental error. It appears that this strain of *S. fendleri* is highly if not completely self-compatible.

Table 6.—*Results of hand pollinations in Solanum jamesii, in 1921 and 1922.*

Selfed.

Plant.	Number of—		Plant.	Number of—	
	Flowers pollinated.	Seed balls.		Flowers pollinated.	Seed balls.
No. 2–5	4	0	No. 15	3	1
No. 3 (F)	7	[1]0	No. 16	7	0
No. 3–1	4	0	No. 17	9	1
No. 3–3	4	0	No. 18	3	0
No. 3–5 (F)	2	0	No. 19	8	0
No. 3–6	5	0	No. 20	7	0
No. 4	3	0	No. 21	7	0
No. 4–1	6	0	No. 22	12	0
No. 4–2	7	1	No. 24	8	0
No. 4–3	2	0	No. 27	5	0
No. 4–5	3	0	No. 28	6	0
No. 9	2	0	No. 29	8	0
No. 10	4	0	No. 30	4	1
No. 11	2	0	No. 31	6	1
No. 13	21	0			

Crosses Between Different Plants Within the Species.

Parents.	Number of—		Parents.	Number of—	
	Flowers crossed.	Seed balls.		Flowers crossed.	Seed balls.
No. 1×No. 12	3	0	No. 3×No. 13	1	0
No. 1×No. 13	2	0	No. 4 (F)×No. 3 (F)	1	0
No. 2–1×No. 16	2	0	No. 4–6×No. 16	5	1
No. 2–3×No. 16	4	0	No. 8×No. 13	12	0
No. 3×No. 3 (F)	3	1	No. 14×No. 13	5	0
No. 3×No. 8	1	0	No. 26×No. 3–4 (F)	2	0

[1] One small seed ball started to develop, but fell off when about one-eighth of an inch in diameter. It contained no seeds. Later in the season this plant produced normally developed seed balls, both naturally fertilized and inbred, under paper sacks.

The 29 plants of *Solanum jamesii* grown from tubers and listed in Table 6 represented 23 known different clons, and these were selfed in a total of 169 flowers. Only five seed balls were obtained, one from each of five plants. There is some pollen impotence in this species, but in most cases at least half of the pollen is vigorously viable. It appears that this stock is either only feebly self-compatible or that abscission was very decided under the particular conditions of growth. Of 12 combinations in crosses only two succeeded, which suggests that cross-incompatibility is in evidence.

The plants of *Solanum maglia* which have thus far been grown at Presque Isle have all been so highly pollen sterile that they could not be expected to function as pollen parents irrespective of any real incompatibilities that might be present.

The compatibility between the various wild species and between these and the cultivated varieties awaits the completion of investigations now under way.

RESULTS OF THE STERILITY SURVEY.

The survey has clearly shown that two types of sterility exist in cultivated potatoes: (1) Sterility from nonblooming and abscission and (2) pollen sterility or one-sided impotence, giving loss of maleness. In wild species as grown at Presque Isle, early abscission of flowers is rarely seen, but in certain species pollen sterility is marked, and there are also evidences of physiological incompatibilities. In the hybrids between the two species *Solanum fendleri* and *S. chacoense* there is very decided impotence of both pistils and stamens.

The sterility from nonblooming to a large degree can be overcome for seed-breeding work by growing varieties under cool-season conditions such as prevail at Presque Isle. There are without doubt some variations in the potency of pollen in fully developed flowers of a single variety, possibly even for the various flowers of a single cluster, and it may be possible that special conditions may shift the pollen of a variety even from class 1 to class 3 or the reverse, but there has been no indication of this in studies made thus far.

Success in obtaining seed depends decidedly on using as male parents varieties which yield the most viable pollen. But even in the best pollen producers among the cultivated potatoes there is much abortion of pollen. As a group these varieties are decidedly low in maleness but relatively high in femaleness.

Other studies of the condition of potato pollen in its relation to sterility include those of Turner, Dorsey and Breeze, respectively. In studies of the pollen of 11 leading commercial varieties grown at Presque Isle, in 1918, Turner [2] found a very high percentage of the grains to be imperfect. In the 61 seedlings studied he reported a wide range of variability in the quality of the pollen, with germination ranging from 0 to 75 per cent. From tests of pollen from plants grown without fertilizer and with different ratios of fertilizer ingredients he concludes that nutrition has a marked effect on the viability of pollen. Dorsey (*3*) found that a large percentage of the pollen of several of the best-known varieties grown in Minnesota was imperfect. He concludes that the development of the pollen

[2] From unpublished manuscript by Thomas W. Turner.

grains is stopped after they are liberated from the tetrad. Breeze (*1*) has distinguished three conditions of pollen degeneracy in the potato:

(1) Shriveled and empty pollen grains. In this case deterioration was found to occur after the formation of the pollen mother cell, and rarely before the formation of the tetrads.

(2) Hypertrophied or swollen grains.

(3) Absence of pollen grains. In the Up-to-Date variety, in which this condition occurs, apparently normal pollen mother cells were found in very young anthers, but no reduction division was observed.

In a later paper (Gardeners' Chronicle, ser. 3, v. 73, p. 176 and 188), Breeze reports the presence of minute amœbæ in the anthers of Up-to-Date, which she considers may cause degeneration of the pollen mother cells.

Much has been written regarding the immediate cause of sterilities in cultivated potatoes and a brief summary of this point may be made here. A view most generally advanced is that the conditions of fruitlessness in the potato are due to the high degree to which vegetative reproduction by tubers is developed. Two conceptions have been advanced as to how this relation may operate: (1) That there is direct and immediate correlation either in direct competition for food material or in correlative stimulations resulting in what may be called correlative sterility and (2) that a general degeneration of sex organs frequently results from long-continued cultivation with selection for vegetative vigor, giving a systemic condition which may be called plethoric sterility.

The idea of correlative sterility due to a direct antagonism between asexual means of propagation and sexual or seed reproduction is an old conception. It has been applied to such cases of sterility as are observed in various tuber, fleshy root, bulb, and rhizome-producing plants of which mention may be made of the cultivated varieties of the potato, sweet potato, sugar cane, and various species of Lilium and Hemerocallis. It has indeed seemed very logical and in harmony with well-recognized phenomena of compensations in growth that vegetative organs which are rapidly storing food may divert and utilize the available food being manufactured in a plant, so that the embryos of the seed are virtually starved to death during development, or perhaps the essential organs of the flowers are so poorly nourished that they are not able to function previous to fertilization. This view has been very generally held since the time of Gesner (*6*, p. 53), Medicus (*16*, p. 202), and Knight (*14*, p. 57). It was emphasized by Darwin (*2*, p. 206, 411) in what he called the "compensation of growth" and by Goebel (*7*, p. 207), in "quantitative correlation." An excellent statement of this view with reference to the potato has more recently been given by Jones (*8*).

That the doctrine of a direct correlative sterility is to be generally applied as thus conceived is now much to be questioned. Bearing on this condition, there are several lines of evidence, all of which point to this conclusion:

(1) The classical cases of so-called correlative and of plethoric sterility in such plants as the true lilies (Lilium), daylilies (Hemerocallis), and sugar cane are now found to involve such types of sterility as incompatibility and intersexuality. In intersexes fruitfulness is limited to hermaphrodite flowers or to female flowers which are properly pollinated with viable pollen from hermaphrodite or male flowers. Thus clonal varieties of the sugar cane or of the potato which are male sterile are able to produce fruit and seeds in abundance in response to good pollen.

In physiological incompatibility, well exemplified in the lilies, fruit and seed production depends on the stimulus of compatible fertilizations, and the bulb or tuber forming plant is consequently found to be fully capable of developing seeds when the proper and compatible pollinations are made.

(2) Experimental proof of a direct and simple competition for food between tubers or bulbs and the forming seeds is lacking. The older statements frequently quoted that the flowering branches of such plants as *Lilium candidum* and *Hemerocallis fulva* will produce fruit and seeds only when they are cut and placed in water and that the removal of aerial bulblets from such plants as *Lilium tigrinum* and *Ficaria ficaria* will lead to seed formation are incorrect. This matter has been tested carefully in experiments at the New York Botanical Garden with results showing that when pods are produced in such cases the plants are to some degree self-compatible and able to produce pods on branches left attached, provided the same care is taken in making the pollinations.

Experiments with the potato which attempt to test for correlative sterility have all given negative results, at least since the favorable results reported by Knight (*14*, p. 58). In an experiment of this sort East (*4*, p. 432–433) prevented the formation of tubers in plants of the three varieties Rural New Yorker No. 2, Green Mountain, and Irish Lemon. In comparing treated with untreated plants he found no increase of apparently good pollen, and to pollinations of 50 plants of each he obtained 6, 9, and 2 fruits, respectively, for the treated, and 4, 8, and 4 fruits for the untreated. The marked fruitlessness of these varieties to self-pollination was not changed by this treatment.

It would seem that a critical experimental test of a direct correlative sterility in potatoes could be made by grafting branches on species of Solanum that do not form tubers. A few years ago an extensive experiment of this sort was conducted by Prof. C. H. Myers and an assistant, W. I. Fisher, at the Agricultural Experiment Station of Cornell University. The results have not been published, but a copy of the report has been kindly furnished by Professor Myers to the writers. Branches of 16 varieties were grafted on various species of Solanum which do not form tubers. The varieties thus used were Beauty of Hebron, Blue Victor, Carman No. 3, Early Ohio, Early Rose, Green Mountain, King Edward VII, Moravia, Pat's Choice, Phoebus, Rural New Yorker, Sir Walter Raleigh, State of Maine, Vermont Gold Coin, Wohltmann, and an unknown sort. Most of the grafts were made on *Solanum ciliatum*, *S. sysimbrifolium*, *S. miniatum*, and *S. nigrum*. In all, 200 successful grafts were made, and the plants were grown to good maturity out of doors in a garden. Many careful hand pollinations (evidently self) were made on flowers, but only one seed ball was obtained from the whole lot. In these grafted plants there was no tuber formation to draw food from the aerial parts. The results are positive in indicating that fruitfulness in these plants is not increased when the qualitative competition for food between vegetative organs and organs of seed production is removed. The sterilities to own pollen, here due in large part to impotence of pollen, or also to abscission were not removed by such experimental methods. There was no indication in the results that the nature of the flowers and of their sex organs was influenced or changed.

(3) In a careful study of the osmotic pressures in potato plants with reference to the distribution of food at various stages of growth Lutman (*15*) has shown that while a superior osmotic pressure seems to be necessary for the formation and growth of new sprouts the growth of berries (fruits) and of tubers can not be thus accounted for, since the osmotic pressures in these organs are the least of any in the plant. Lutman points out that there appears to be a pumping action of the sieve tubes, but that a study of the comparative osmotic pressures does not reveal the manner in which they may induce the observed flow of food materials even to the tubers.

(4) For the cultivated varieties of the potato the evidence is clear that when conditions favor blooming the use of viable pollen gives fruit in abundance. Fruit is often abundantly found in the field, especially on varieties having considerable good pollen. Furthermore, a study of the comparative yields of tubers and seed balls for plants of such a variety (Lookout Mountain or McCormick) by Newman and Leonian (*17*, p. 14) has shown that "in most cases the heaviest tuber production, the richest vegetative growth, and the largest seed productions go hand in hand." There are, however, various conditions influencing the growth of plants, the yield of tubers, and the production of seed balls. Under certain of these conditions there may be internal regulation of development that directly or indirectly determines whether the success or failure of the stimulation of fertilization is to be effective.

The main point of the evidence noted above regarding the setting of seed is that under favorable conditions for blooming, potatoes are well

able to produce fruits in abundance. There appear to be no direct correlations with competition for food between vegetative organs of storage and fruits with seeds which determine or even strongly influence fruit production.

There remains, however, the question whether correlative conditions directly determine or influence either the abscission of flowers or the relative development of the sex organs in flowers, and particularly of the stamens and pollen.

The abscission of flower buds and flowers is highly variable and is obviously responsive to environmental influences. Special studies of this condition in the potato by Young (*27*, p. 17) "suggest rather definitely that moderately cool weather, especially at night, favors the setting of seed and that a gradually falling temperature with a moderate amount of moisture is especially favorable." Young notes that "it is not unusual for a wave of warm weather in early summer to be followed by the nearly or quite complete shedding of the buds and blossoms of the potato." That their environmental conditions operate through internal conditions and correlations is quite obvious. The studies which Kendall (*9*) has made with a related genus (Nicotiana) indicate that temperature is an important factor influencing abscission.

When flowers of healthy potato plants remain attached until they are fully open and pollen is dehiscing, the general condition of stamens and the quantity of viable pollen appears to be very constant, at least for the varieties grouped in class 1. This statement is based on comparative studies of varieties grown at the New York Botanical Garden and at Presque Isle of early and late plantings of the same variety and of plantings grown with different fertilizers. There may be variations giving different grades of either maleness or femaleness or of both, and such variations may be rather irregular or decidedly cyclic. It would seem that the comparatively short blooming period of a potato plant limits and largely precludes the possibility of such noteworthy changes in sex as are seen in the successive flowers on a plant of *Cleome spinosa* (*22*).

The influence of various infectious diseases on the quality of pollen has not been carefully studied by the writers. In the varietal test plats grown at Presque Isle diseased plants are rogued early, and material for adequate comparative tests of pollen from diseased and healthy plants of varieties or seedling strains normally having considerable viable pollen (in class 1) was not available.

It is noteworthy that under conditions of abundant flowering (and under the same conditions) varieties like McCormick, Green Mountain, Australian Blue, and Berrick exhibit characteristic differences in the degree of pollen sterility which are remarkably constant for each and which enable the general grouping into classes 1, 2, 3, and 4 to be made, as indicated in preceding pages. There is also evidence that there is no immediate and direct correlative compensation that causes pollen sterility. Pollen sterility is decidedly an inherent characteristic. There is obviously some hereditary basis for the condition.

In an effort to determine the hereditary values of different grades of pollen sterility in potatoes Salaman (*18*) considers pollen fertility and pollen sterility rather sharply as contrasted characters and suggests that male sterility is here "a dominant hereditary char-

acter." In a later paper, Salaman and Lesley (*19*) extend this conception.

It is clear that there are many grades of pollen abortion in cultivated potatoes and that even in the highest grade of pollen fertility there is much abortion. There is no sharp distinction between presence and absence of good pollen. There is scant evidence that any varieties most highly potent as males will breed true for this condition. But abundant evidence is found that they usually do not breed true and that regression to lower grades of pollen sterility may be different for reciprocal crosses. The interpretation that such results (*19*) are due to specific hereditary factors which are distributed differently to the spores in pistils than to the spores in stamens, through a somatic segregation that precedes the regular reduction divisions, is an expression of the view that there must be direct hereditary bearers of pollen sterility and pollen fertility. It seems to the writers that the presence of pollen sterility of some degree in all cultivated varieties and seedlings derived from them is proof that pollen sterility is really perpetually dominant. The whole race of cultivated potatoes is decidedly low in maleness. The hereditary values of the different grades and the type of inheritance involved can only be determined by an extensive study of the whole group of cultivated varieties and of their progenies in considerable numbers.

Direct evidence is at present lacking as to the origin of the condition of male sterility in the potato. The presence of this type of sterility in certain wild species suggests possible inheritance from a wild ancestor. Whether a very general one-sided sterility affecting maleness alone can arise in a progeny through hybridization is an unsettled point. In general, sterility from hybridity typically affects both maleness and femaleness quite alike. Variation in sex is a widespread phenomenon among plants and animals; often it gives a wide range of intersexes with females, males, and various sorts of imperfect as well as perfect hermaphrodites. In some wild species as well as in the cultivated potatoes there is a very general loss of male potency, with little or at least relatively less loss of femaleness. These conditions exist in species propagated exclusively by seeds as well as in those that readily propagate by vegetative means.

It is to be noted in this connection that the true sex stage in the alternation of generations in flowering plants is reduced to a short-lived, relatively simple but highly specialized dependent structure. Sexual reproduction has become more and more a matter of seed producing, and fruit and seed development has become decidedly interrelated with the vegetative growth of the plant that bears the spores. It may well be that in the general evolutionary trend to this condition the internal regulation of development and the influences of vegetative vigor may result in a systemic or plethoric sterility, which in the case of the potato seems to affect maleness more than femaleness, and that in time this becomes decidedly if indirectly hereditary.[3]

[3] Since this bulletin went to the printer, an article by W. J. Young (Amer. Jour. of Botany, v. 10, no. 6, pp. 325–334, June, 1923) reports that blasting or nonblooming and pollen sterility in the potato involve characteristic differences in the degeneration of germ cells. In the blasting and shedding of flowers under unfavorable weather conditions there is an early degeneration of both ovules and anther contents. But in pollen sterility disintegration of pollen grains occurs when they are nearly mature and does not lead to the shedding of flowers. Young also points out that varieties which produce no viable pollen may set fruit and produce seed.

SUMMARY.

The nonblooming habit of the potato with early abscission of the flower buds and flowers when grown under certain conditions is a direct influence of environment. Varieties which bloom in profusion in northern Maine rarely or never bloom at the New York Botanical Garden. This habit is a most decided limitation to fruit production, irrespective of the condition of pistils and stamens when flowers are produced.

Relatively few of the cultivated varieties and seedlings produce viable pollen in considerable quantities and are able to function as pollen parents. The highest potency of pollen in these is decidedly low.

Nearly all varieties, if not all, are able under conditions of favorable blooming to produce seed balls in response to proper pollination with viable pollen.

As a group, the cultivated varieties of the potato exhibit a one-sided sterility which chiefly involves maleness.

There is no conclusive evidence of a real physiological incompatibility in the fertilization of cultivated varieties, but there is positive evidence of such sterility in the wild species, *Solanum chacoense*.

F_1 hybrids between *S. fendleri* and *S. chacoense* appear to be completely impotent as males and also as functional females.

Breeding from seed in potatoes can best be undertaken when varieties bloom in profusion. Under such conditions success in obtaining seeds depends chiefly on the use of pollen that is viable.

So far as this study has been made, pollen in anthers of fully mature flowers of any one variety appears to be very constant in quantity, range of abortion, general character, and viability.

The production of tubers in which much food is stored does not directly influence and prohibit the formation of fruit by the potato.

LITERATURE CITED.

(1) Breeze, Mabel S. G.
1921. Degeneration in anthers of potato. *In* Gard. Chron., ser. 3, v. 70, p. 274–275.

(2) Darwin, Charles.
1868. The variation of animals and plants under domestication. v. 2, 568 p. New York.

(3) Dorsey, M. J.
1919. A note on the dropping of flowers in the potato. *In* Jour. Heredity, v. 10, p. 226–228, fig. 19.

(4) East, Edward M.
1908. Some essential points in potato breeding. *In* Conn. Agr. Exp. Sta., 31st/32d Ann. Rpt. (Bien. Rpt.), 1907/1908, p. 429–447, fig. 8.

(5) Garner, W. W., and Allard, H. A.
1920. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. *In* Jour. Agr. Research, v. 18, p. 553–606, pl. 64–79.

(6) Gesner, Conrad.
1577. Epistolarum medicinalium . . . libri III. 140 p., illus. Tiguri.

(7) Goebel, Karl.
1900. Organography of plants. Pt. 1, xvi, 270 p., 130 fig. Oxford.

(8) JONES, L. R.
1903. The diseases of the potato in relation to its development. *In* Trans. Mass. Hort. Soc., 1903, pt. 1, p. 144–156.

(9) KENDALL, JOHN N.
1918. Abscission of flowers and fruits in the Solanaceae, with special reference to Nicotiana. Univ. Cal. Pub. Bot., v. 5, p. 347–428, 10 fig., pl. 49–53.

(10) KLEBS, GEORG.
1903. Willkürliche Entwickelungsänderungen bei Pflanzen. iv, 166 p., 28 fig. Jena.

(11) 1904. Ueber Probleme der Entwickelung. *In* Biol. Centralbl., Bd. 24, p. 257–267, 289–305, 3 fig.

(12) 1905. Ueber Variationen der Blüten. *In* Jahrb. Wiss. Bot. [Pringsheim], Bd. 42, p. 155–320, 27 fig., pl. 8.

(13) 1910. Alterations in the development and forms of plants as a result of environment. *In* Proc. Roy. Soc. Lond., ser. B, v. 82, p. 547–558.

(14) KNIGHT, THOMAS ANDREW.
1807. On raising new and early varieties of the potato. *In* Trans. Hort. Soc. London, v. 1, pt. 1, p. 57–59.

(15) LUTMAN, B. F.
1919. Osmotic pressures in the potato plant at various stages of growth. *In* Amer. Jour. Bot., v. 6, p. 181–202, 2 fig.

(16) MEDICUS, FRIEDRICH KASIMIR.
1803. Pflanzen-physiologische Abhandlungen. Bd. 2, 244 p. Leipzig.

(17) NEWMAN, C. C., and LEONIAN, L. A.
1918. Irish potato breeding. S. C. Agr. Exp. Sta. Bul. 195, 28 p., 19 fig.

(18) SALAMAN, REDCLIFFE N.
1910. Male sterility in potatoes, a dominant Mendelian character; with remarks on the shape of the pollen in wild and domestic varieties. *In* Jour. Linn. Soc. [London], Bot., v. 39, p. 301–312.

(19) ——— and LESLEY, J. W.
1922. Genetic studies in potatoes; sterility. *In* Jour. Agr. Sci., v. 12, p. 31–39, pl. 2.

(20) SETCHELL, WILLIAM ALBERT.
1920. Stenothermy and zone invasion. *In* Amer. Nat., v. 54, p. 385–397.

(21) 1920. Geographical distribution of the marine spermatophytes. *In* Bul. Torrey Bot. Club, v. 47, p. 563–579.

(22) STOUT, A. B.
1923. Alternation of sexes and intermittent production of fruit in the spider flower (Cleome spinosa). *In* Amer. Jour. Bot., v. 10, p. 57–66,, 1 fig. pl. 6.

(23) STUART, WILLIAM.
1915. Group classification and varietal descriptions of some American potatoes. U. S. Dept. Agr. Bul. 176, 56 p., 19 pl.

(24) 1915. Potato breeding and selection. U. S. Dept. Agr. Bul. 195, 35 p., 2 fig. 16 pl.

(25) ——— and others.
[1922.] Report of committee on varietal nomenclature and testing. *In* Proc. 8th Ann. Meeting Potato Assoc. America, 1921, p. 60–72.

(26) TAYLOR, GEORGE M.
1910. The cross-fertilization of the potato. *In* Gard. Chron., ser. 3, v. 48, p. 279.

(27) YOUNG, W. J.
1922. Some phases of breeding work and seed production of Irish potatoes. S. C. Agr. Exp. Sta. Bul. 210, 20 p., 3 fig.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1924